NATURE'S LIFELINE: PRAIRIE AND NORTHERN WATERS

CANADA WEST FOUNDATION

NATURE'S LIFELINE:

PRAIRIE AND NORTHERN WATERS

A TECHNICAL REPORT SPONSORED BY
CANADA WEST FOUNDATION
WITH SUPPORT FROM
DEVONIAN GROUP OF CHARITABLE FOUNDATIONS

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CANADA WEST FOUNDATION

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403) 264-9535

ISBN 0-919251-48-X

Canada West Foundation

Canada West Foundation is an independent, non-partisan research organization registered as a Canadian charitable organization. It is funded by individual memberships, by grants from corporations and institutions, and by grants from the western provincial governments, Yukon and the Northwest Territories. Its main objectives are:

1) to initiate and conduct practical and imaginative research programs regarding the economic and social characteristics and potentials of the west and north;

2) to initiate and conduct informational and educational programs to encourage an appreciation of our Canadian heritage and the future opportunities available to western Canadians.

The Foundation seeks to promote public understanding on significant issues that relate to the maintenance and development of a strong and viable western Canada. It publishes impartial research findings which are made available to decision-makers, members, and the news media in order to contribute to public understanding of social and economic issues of the day.

The Devonian Group

The Devonian Group of Charitable Foundations is a privately financed group of charitable foundations located in Calgary, Alberta, established by the late Mr. Eric L. Harvie, Q.C., and members of his family to collect and preserve articles of historical, cultural and scientific interest. The Group's principal areas of activity are public parks, applied scientific research and historic preservation.

In the past eight years, 86% of the available resources (capital plus income) of the Devonian Group has been put actively to work across Canada in numerous large projects which benefit the general public.

FOREWORD

The presence of fresh water in the form of rivers, lakes, and groundwater determined the history of man's occupancy of the region we know today as western Canada. Water continues to be critical to the maintenance and enhancement of our quality of life. Whether our lifestyles will be stunted in the face of growing water uses, or whether a continued increase in productivity can be sustained, will depend upon the future availability and quality of this essential resource.

This report, Nature's Lifeline: Prairie and Northern Waters, is the result of a study undertaken as a joint venture by the Canada West Foundation and the Devonian Group of Charitable Foundations. Its purpose is to facilitate informed public debate. It provides western Canadians with a comprehensive and coordinated overview which deals with the varied and often complicated aspects of the region's water resources. The report contains detailed and carefully researched information on water supplies and usages, potential future demands, and an inventory of the issues which must be addressed and resolved.

Although current and future water related issues facing western Canadians are identified, the report does not provide specific recommendations regarding how these issues should be resolved. Rather it provides all interested individuals and organizations with facts and a perspective on the manner in which water uses are interrelated.

This document provides a jumping off point from which a broader process of public debate, research, and decision making will grow. To be successful, this process must involve the public as a whole, the political and governmental structures, the academic and scientific communities, and the broad spectrum of industries from agriculture to energy and manufacturing.

The problems of the past -- drought, flooding and conflicting uses and demands for water -- are still very much with us. Despite technological advances in water control, the supply is still in the hands of nature and many areas still suffer from wide seasonal fluctuations which affect human activities ranging from agricultural production to northern transportation and even the urban luxury of lawn-watering.

The most basic challenge facing us will be to use our water in such a way that the supplies are maintained in a satisfactory state of balance with a growing demand. Unlike other resources where supply is relatively constant and easy to quantify, water supplies fluctuate widely from one year to the next. In a similar fashion, demand can increase or decrease dramatically depending upon the cost and the practical availability of the resource. Finally, we are becoming more and more aware of water pollution which decreases the ability of subsequent users to obtain adequate supplies. When water is polluted, the supply must be discounted: the less pollution, the greater the supply of usable water to downstream users. Only careful husbandry of the resource based upon a clear understanding of the complexities of changing water usage will maintain the delicate balance between supply and demand.

If we are to be successful in maintaining a balance between supply and demand in the future, our political and administrative mechanisms will need to be refined. The lead time needed for all aspects of water resource decision making is longer than for other resources. This report identifies five major issues which western Canadians need to address: water pricing, water pollution, water diversion, water management, and future research needs.

Water, in most cases, is now delivered to its variety of users at well below the cost of supplying the service. Should there be a rethinking of our present attitudes about water as a cheap and readily-available resource? Should users pay the full cost?

The increasing use of chemicals in agriculture and manufacturing, and the need to treat rising volumes of effluent from expanding urban areas, decreases water quality. Resource development, from forestry to conventional oil and gas, oil sands and heavy oil, will place greater demands on existing supply as well as increase the problem of quality. Such uses will be in conflict from time to time with water demands for recreation and subsistence uses such as hunting, fishing, and trapping.

Most rivers in the Study Region flow northward to the Arctic Ocean and Hudson Bay, while the great bulk of population is in the south. Should water be diverted from the northern to southern regions, particularly for irrigation in the semi-arid grain-producing areas of southern Alberta and Saskatchewan?

Canada's water resources are now managed by a large number of federal, provincial and regional agencies. The coordination of their activities is often difficult, given the many jurisdictions which are affected by changes in water usages. Is it time for a coherent region-wide water policy to be established and implemented?

Water resource research requires the assessment of a great deal of varied and detailed data, is time consuming, and very expensive. An incredible amount of research has been done by numerous public and private agencies and individuals, as is attested to by this report's selected bibliography. Yet if we are to resolve the issues identified above, extensive new information and analysis is required. Who should do this research? Who should pay for it?

One issue which is often mentioned in Canadian water resource reports is conspicuously absent from our list of major issues: the potential export of Canadian water to the United States. Although the topic is discussed in the body of the report, we do not believe it to be a salient issue.

Water, which has occupied a relatively low priority in the public and political consciousness, is about to become one of the major resource issues in the region. Will we be equipped to deal with it? Will we have the knowledge and the judgment to sift the alternatives and make the decisions which will assure that water is a well-used and effective servant in the development of the west and the north?

This study provides a benchmark, a solid starting line. It is published with the confidence that the many individuals, from layman to expert, householder, civil servant, industrialist, farmer and rancher, and native peoples will be able to use it in their own process of questioning, analysis and, above all, involvement.

The publication of this study is only the first step of a journey in which many will join to seek and find the best answers for the critical decisions ahead on water management.

D. K. ELTON, President
Canada West Foundation;
Chairman, Management Committee

A. E. PALLISTER, Associate
Devonian Group of Charitable Foundations;
Chairman, Board of Advisors

The Material In This Report
Was Compiled And Prepared
For Canada West Foundation
And
Devonian Group Of
Charitable Foundations

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ACKNOWLEDGEMENTS

It would give us great pleasure to thank individually all those who contributed to this study; but unfortunately, this would be difficult. Literally hundreds of people supplied information, reviewed drafts of the report, and offered advice and direction. Only a few can be thanked personally, but all should know that we greatly appreciated their help.

Two groups, in particular, stand out: the Board of Advisors and the Management Committee.

The Board of Advisors was formed by the Devonian Group of Charitable Foundations to provide advice concerning the direction of the study. The Board represented a wide variety of knowledge and gave the study a broader perspective than it would otherwise have had. Its members were:

Dr. A. Ernie Pallister Chairman	President Pallister Resource Management Ltd., and Associate, Devonian Group of Charitable Foundations, Calgary, Alberta
Mr. W. (Bill) Berry	President Palliser Water Resource Consultants Ltd. Regina, Saskatchewan
Mr. Bert Hargrave	Member of Parliament Medicine Hat, Alberta
Mr. Keith Henry	President C B A Engineering Ltd. Vancouver, B.C.
Mr. R. (Bob) Hornal	Northern Pipeline Agency Yellowknife, N.W.T.
Prof. Ed Kuiper	Dept. of Civil Engineering University of Manitoba Winnipeg, Manitoba

The Management Committee was formed by the Canada West Foundation to provide advice and guidance of a more specific nature. Its members commented more directly on the content of the report, while giving advice of a general nature as well. They also provided valuable access to many reports and documents that were at their disposal. Its members were:

Dr. David Elton Chairman	President Canada West Foundation Calgary, Alberta
Mr. Dan Billing	Science Advisor Government of the N W T Yellowknife, N.W.T.
Mr. Stan Blackwell	Chief, Water Management Services Saskatchewan Environment Regina, Saskatchewan
Mr. Denis Davis	Regional Director Inland Waters Directorate Environment Canada Regina, Saskatchewan
Dr. Harry Hill	Director, Prairie Farm Rehabilitation Administration Dept. of Regional Economic Expansion (Canada) Regina, Saskatchewan
Prof. Arleigh Laycock	Dept. of Geography University of Alberta Edmonton, Alberta
Mr. Peter Melnychuk	Assistant Deputy Minister Alberta Environment Edmonton, Alberta
Mr. Gordon Spafford	President UNIES Ltd. Winnipeg, Manitoba

As well as giving of their own time, members of the Management Committee and Board of Advisors put us in contact with members of their staffs and others who provided valuable information and reviewed many parts of the report. Though some of these people remained anonymous to us, their input was often large and very helpful. A number of errors were corrected, some

ERRATA The following two names were mistakenly left off the list of Management Committee members:

Mr. Tom Weber	- Director, Water Resources Branch, Dept. of Natural Resources, Government of Manitoba
Mr. Anthony Dorcey	- Assistant Director, Westwater Research Centre, Univ. of B.C.

misleading or vague sections rewritten, and much useful information added. In particular, numerous civil servants spent many hours reviewing sections of the report before they were finalized. We are greatly indebted to these people.

A considerable amount of background information was provided under contract by a number of consultants, academics, and students. These were:

David F. Dickins Engineering Company, Yellowknife, N.W.T.
James F. MacLaren Engineers, Edmonton, Alberta
MLM Ground-Water Engineering, St. Albert, Alberta
W-E-R Engineering Ltd., Calgary, Alberta
UNIES Ltd., Winnipeg, Manitoba
Dr. John FitzGibbon, Saskatoon, Saskatchewan
Mr. Joe Lennon, Winnipeg, Manitoba
Dr. Alastair Lucas, Calgary, Alberta
Mr. Frank MacKenzie, Edmonton, Alberta
Mr. Geoff Travers, Edmonton, Alberta

As well as providing their reports, these contributors were available for discussion and elaboration of their work, and frequently provided valuable additional information. Much of the work of these companies and individuals was incorporated into the final report and provided the basis for some additional work. The background reports available from Canada West Foundation are listed on a separate page.

The staff of the Canada West Foundation were helpful in many respects. As well as typing the report and taking care of administrative concerns, they provided valuable feedback concerning many aspects of the study. The staff members included:

Dr. David K. Elton	President
Mrs. Joan Hudson	Communications Consultant
Dr. R. A. D. Beck	Consulting Economist
Ms. Nancy Sanford	Administrative Officer
Mrs. Jeannette Robertson	Secretary
Mrs. Sue Joyce	Secretary
Mrs. Wendy Sykes	Publications Officer

Ms. Kim Combot	Secretary
Ms. Penny Roberts	Secretary

The draftspersons for the report were:
- Susan Popowich
- Keith Cornelius
- Igor Gaspar
- Larry Meed

And finally, there are those friends and acquaintances, business associates and colleagues, and countless others who asked questions and triggered new ideas for the report. And our wives, who provided unrelenting support and encouragement.

Thank you,

Bob Lane & Gary Sykes

BACKGROUND TO THE STUDY

Study History and Objectives

The Canada West Foundation, in pursuit of its goal to focus public attention on significant issues facing western Canada, has ranked the assessment of problems and opportunities in water resources management among its highest priorities. In late 1979, the Foundation began the preparation of an overview report of water in western Canada, including a summary of the uses to which it is put, the constraints presently faced by its users, and the foreseeable limitations and opportunities of the future.

Consultation with senior water managers and scientists revealed that considerable funds had been expended in the past to produce many volumes dealing with western water resources. These reports have tended to address specific issues in relatively small geographic areas. A broader-based review, which would incorporate the findings of these many studies, was needed. The interest of provincial, territorial, and federal water management agencies, and of academics and the private sector, became apparent by their willingness to assist the Foundation in advisory capacities.

In the spring of 1980 the Devonian Foundation joined with the Canada West Foundation and initiated a jointly sponsored study to generate a report which would describe all significant water resource management issues, while refraining from taking sides on controversial issues, or from offering specific recommendations pertaining to them. The intent was to develop a report that could be subsequently used by the Canada West Foundation and others as a basis for the development of water management policy recommendations. Furthermore, it was felt that this overview report would serve as a helpful guide to policy-makers, politicians, resource managers and researchers, and many varied groups interested in information about water in this large region.

The objectives of the study were:

1. to present a comprehensive overview of factual information regarding the supply, quality, and current use of western Canada's water resources (including a discussion of all significant uses, and conflicts in use; legal, administrative, and institutional arrangements; and interjurisdictional obligations);

2. to report on the extent of anticipated future water use patterns and projects and their impact upon future economic, social, and environmental factors;

3. to identify the extent and kind of participation in water resource planning and management; and

4. to identify the areas of water resource planning and management that require further investigation.

Study Area

The geographic scope of the study was limited to those regions which drain to the Arctic Ocean, Hudson Bay, and the Missouri River. Throughout the report this is referred to as the Study Region. The remaining areas in western Canada, which drain to the Pacific Ocean and the Bering Sea, were excluded, recognizing that water characteristics and water management issues in the Pacific drainage differ in many important respects from those described herein.

Study Structure and Methodology

To assist the Canada West Foundation in this project, a Management Committee consisting of senior representatives of each of the water management agencies in western Canada, representatives of the academic community, and members of the private sector was formed. While these persons contributed in an advisory capacity as private individuals, they were also able to facilitate access to the important storehouse of information which resides within the water management agencies and water research institutions of western Canada.

A second group, the Board of Advisors, was formed by the Devonian Foundation for the purpose of providing counsel to the director during the progress of the study and to the two Foundations. This smaller group consisted of a chairman and a distinguished water resource individual from each of the four western provinces and the Northwest Territories.

In an effort to capture the suggestions and comments of a wider body of water expertise, a number of seminars were held in major urban areas of the Study Region. These seminars, which consisted of an information session followed by an open discussion, were arranged through the cooperation of interested university and government bodies.

A number of specific reports on water supply characteristics and water use were produced through contractual arrangements, by private consultants and academics. Major sections of these reports have been incorporated in this overview without continuous citation. Information sources referred to throughout the text are listed in the bibliography. A substantial amount of information was also provided by government officials and private individuals.

Canada West Foundation would like to thank the following organizations for helping CWF meet its financial obligations for this study:

Government of Alberta
Government of Northwest Territories
Law Foundation of Alberta
Petro Canada Explorations
Shell Canada Resources Ltd.
TransAlta Utilities Ltd.

BACKGROUND REPORTS TO THIS STUDY AVAILABLE FROM CANADA WEST FOUNDATION

No.	Author	Title	Price*
82-2	D.F. Dickins Engineering	Transportation Use Of Water Resources In Western Canada ISBN 0-919251-50-1	$15.00
82-3	MLM Ground-Water Engineering	Ground-Water Resources Of The Nelson, Churchill And Missouri River Basins And Mackenzie Drainage Basin ISBN 0-919251-52-8	$15.00
82-4	MacLaren Engineers Planners & Scientists Inc.	Industrial Water Use ISBN 0-919251-49-8	$15.00
82-5	Prof.John FitzGibbon Dept. of Geography University of Saskatchewan	Agricultural Use Of Water In Western Canada ISBN 0-919251-51-X	$15.00
82-6	Alastair R. Lucas Faculty of Law University of Calgary	Western Canadian Water Resources Law ISBN 0-919251-53-6	$10.00
82-7	W-E-R Engineering Ltd.	Surface Water Hydrology ISBN 0-919251-54-4	$15.00
82-8	UNIES Ltd.	Future Water Use In Hydro-Electric And Thermal-Electric Generation ISBN 0-919251-55-2	$10.00
82-9	W-E-R Engineering Ltd.	Irrigation Water Use - Western Prairies ISBN 0-919251-56-0	$15.00
82-10	Joseph Lennon University of Manitoba	An Assessment of Information Concerning Recreational And Renewable Water Use In Western Canada	**

* Prices subject to change

** Available on microfiche from Natural Resources Institute, The University of Manitoba, Winnipeg.

SUMMARY OF THE REPORT

For over a decade many western Canadians have raised questions regarding the adequacy of the region's water resources and the wisdom of existing policies that regulate their use. Individual farmers, agricultural organizations, businessmen, chambers of commerce, academics, and recreational and environmental organizations have voiced concerns. As a result of this unease about the region's water resources, the Canada West Foundation and the Devonian Group of Charitable Foundations joined to sponsor and support this comprehensive overview, which brings together and complements the many site-specific water resource studies that have been undertaken by numerous government agencies, industry, and special interest groups.

This report considers those areas of western Canada draining to the Arctic Ocean, to Hudson Bay, and to the Missouri River in the United States. It includes all of Alberta, Saskatchewan, and Manitoba; all of the mainland Northwest Territories; and portions of British Columbia and the Yukon Territory. The remaining area of western Canada, which drains to the Pacific Ocean, is expected to be the subject of a separate study.

The area studied is a region of great water resource contrasts. Countless thousands of lakes dot parts of the Canadian Shield, while vast semi-arid plains lie in southwestern parts. In some years, urban centres and large tracts of cultivated land are threatened by floods. In other years, emergency measures are required to provide water to smaller communities.

Importance of Water

Water is our most precious resource. Its value and fragility are not always appreciated by its many users.

The value of water is admittedly a very difficult concept. Most Canadians have had little basis for applying a commercial value to its use. Water is often considered, like the air we breathe, to be a free good - a necessary item which is not for sale. Because of this, and the generally low cost of obtaining water, there have been few incentives to economize in its use. Even more difficult is the assessment of the value of water in its natural setting, where it serves the fish, wildlife, forests, and grasslands of the outdoor environment, and where it provides immeasurable pleasure by its beauty.

As early as 1857, the importance of water to the agricultural development of the southern prairies was noted by Captain John Palliser, who expressed great concern about the apparent dryness of southern Alberta and Saskatchewan. Nevertheless, agriculture grew, accepting the hardship of dry years, always with faith in the return of better conditions.

In the early years, though railway construction encouraged some spreading out, settlements developed near waterways. Then, particularly with the bold aproach of the Prairie Farm Rehabilitation Administration (PFRA) during the 1930s and 1940s, prairie water developments began to make water more consistently available, and over larger areas. Storage reservoirs were constructed to help offset the sometimes great seasonal and annual variations of supply in agricultural areas. Irrigation diversions, and the construction of wells and dugouts, provided water at increasing distances from the natural drainage systems.

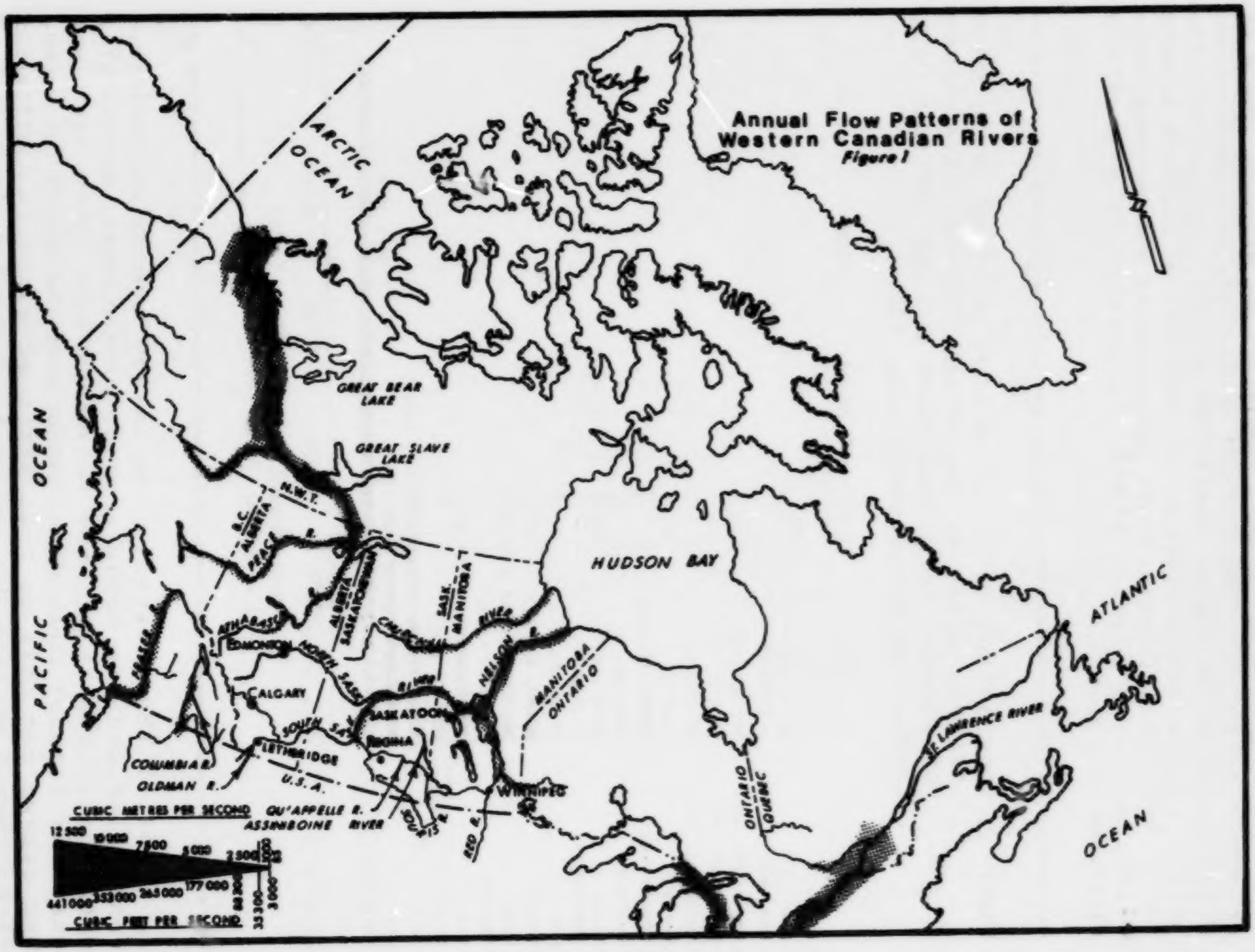
With the encouragement of these programs and improvements in technology, there has been increasing enthusiasm for even more imaginative water management schemes. At the same time competition for water use is increasing. With the growth of concentrated urban populations, resource development, and spiralling energy demands, many other sectors of the economy are beginning to appreciate more fully the value of water.

Water Supplies

The map of Canada's major rivers in Figure 1 depicts graphically the relative size of the various rivers. One striking feature is the magnitude of Canada's northern rivers. The Mackenzie River is one of the largest rivers in North America, ranking third behind the Mississippi and the St. Lawrence. It is over 4 200 kilometres long, discharges an annual average flow of approximately 10 000 cubic metres per second, and covers a drainage area of over 1 800 000 square kilometres...an area larger than France, Germany, Spain, Portugal, Italy, and Great Britain combined.

Most of western Canada's freshwater lies north of the populated region of the country, as over 80% of the natural water supplies are contained in an area populated by fewer than 10% of the region's people.

Over 4 million Canadians live within the confines of the Saskatchewan-Nelson basin. The natural flow of the rivers in this region, although much smaller than the rivers of the north,



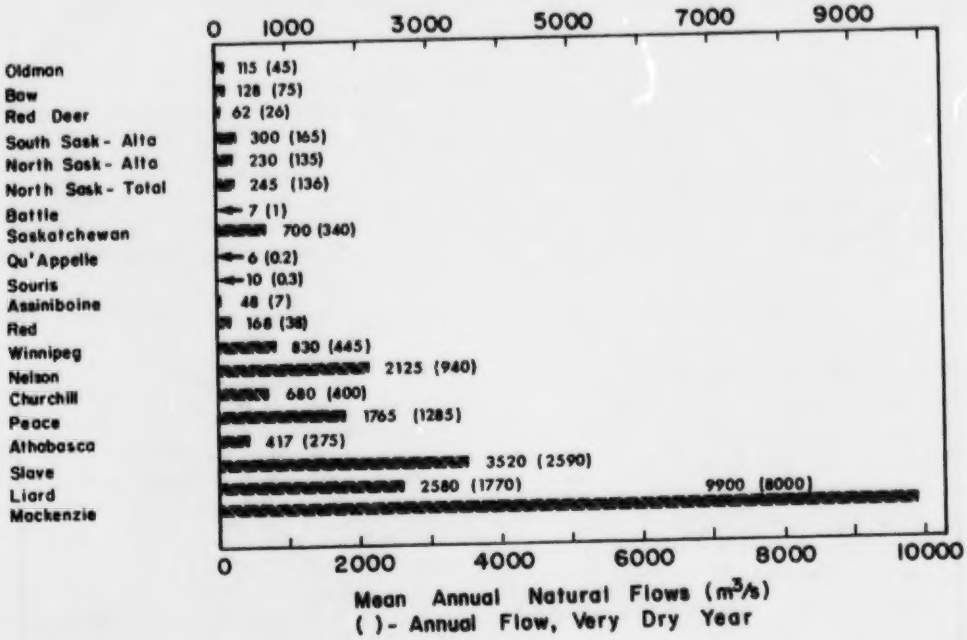
Annual Flow Patterns of Western Canadian Rivers

Figure I

ARCTIC OCEAN
GREAT BEAR LAKE
GREAT SLAVE LAKE
N.W.T.
B.C.
ALBERTA
PEACE R.
ATHABASCA
ALBERTA
SASKATCHEWAN
SASK.
MANITOBA
CHURCHILL
RIVER
NELSON R.
MANITOBA
ONTARIO
HUDSON BAY
ONTARIO
QUEBEC
ATLANTIC
OCEAN
ST. LAWRENCE RIVER
PACIFIC OCEAN
FRASER R.
EDMONTON
NORTH SASK.
RIVER
CALGARY
SOUTH SASK.
SASKATOON
REGINA
LETHBRIDGE
COLUMBIA R.
OLDMAN R.
U.S.A.
WINNIPEG
QU'APPELLE R.
ASSINIBOINE RIVER
SOURIS R.
RED R.
CUBIC METRES PER SECOND
12 500
10 000
7500
5000
2500
1000
CUBIC FEET PER SECOND
441000
353000
265000
177 000
88 300
35 300
3000

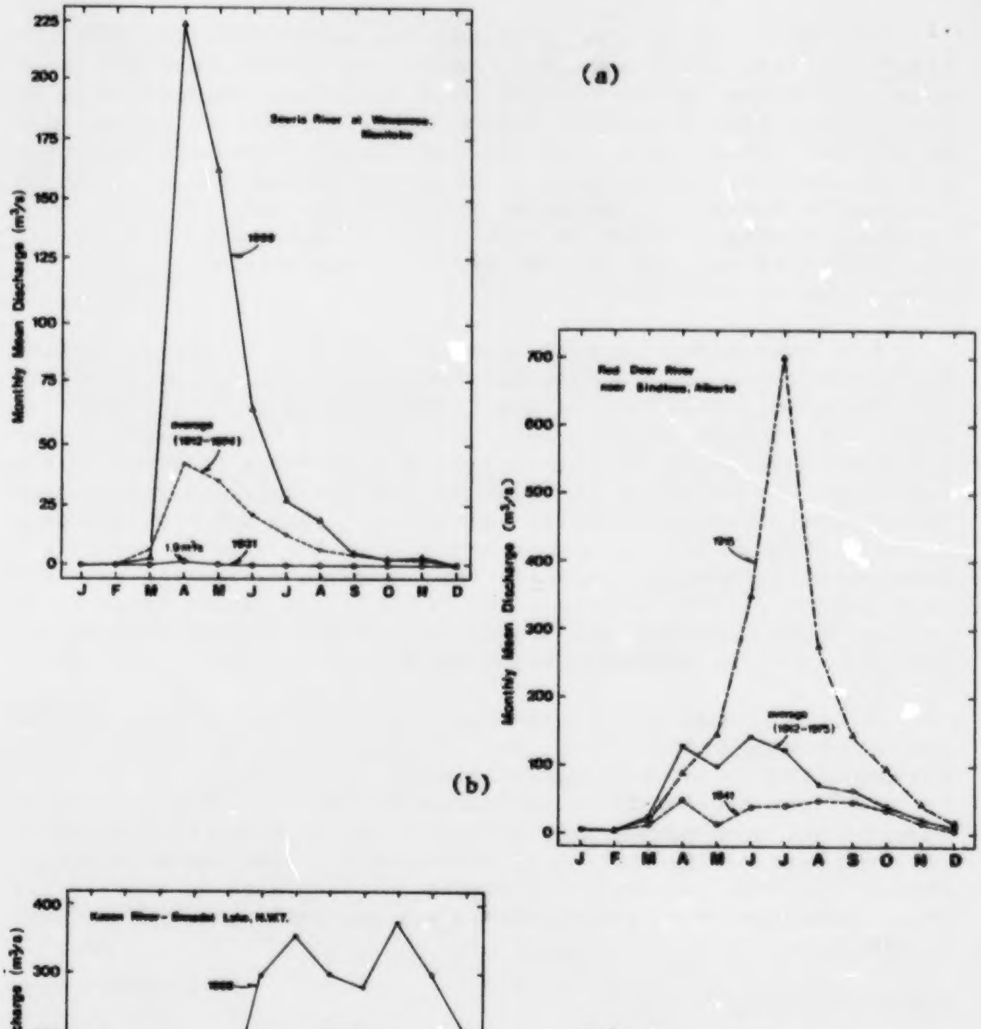
adequately supports the current population and existing levels of economic activity. The contrast between the very small rivers originating on the plains (Battle, Qu'Appelle, Assiniboine), the larger rivers originating in the mountains of southern Alberta (Bow, Red Deer, Oldman, North Saskatchewan) and the very large northern rivers (Peace, Liard, Mackenzie) is graphically displayed in Figure 2.

Figure 2. COMPARISON OF RELATIVE SIZES OF RIVERS IN THE STUDY REGION, USING NATURAL ANNUAL FLOWS FOR THEIR PERIODS OF RECORD, AND NATURAL FLOWS IN A VERY DRY YEAR (WER, 1980a; and Environment Canada, 1980a).



Most of the rivers in the Saskatchewan-Nelson basin are controlled and are being used for hydro power, agriculture, municipal, industrial, and recreation uses. There are times when the flow of these rivers cannot meet the demand for water. One reason for this is that parts of southern Alberta and Saskatchewan are naturally semi-arid. Saskatchewan's Great Sand

Figure 3. EXAMPLES OF VARIABILITY OF FLOWS FOR RIVERS RISING ON: (a) Interior Plains (b) The Cordillera (c) The Canadian Shield.



Hills, which look more like the Sahara desert than western Canada, and periodic dust storms on the prairies are graphic reminders to many prairie residents that they live in an area that is naturally water-deficient.

The problem on the prairies is not that nature does not supply an adequate amount of water, but rather that the water does not always arrive when or where it is most needed. Much of the natural flow of prairie rivers rushes through the region in a 60-90 day period in the spring. As Figure 3 demonstrates, over 60% of the total annual water flow passes through the prairies on its way to Hudson Bay during a three-month period. This not only causes flooding problems in some years; it also means that unless the water is stored in some way it is not available for use at other times of the year.

For over half a century, prairie residents have been seeking ways and means to regulate and control the flow of water within their region. As a result, dams, offstream storage facilities or reservoirs, and irrigation canals are a common sight in the southern part of the prairie provinces. As the population of the region has continued to grow, and new economic activities have been undertaken, governments have taken a real interest not only in managing existing water supplies, but also in examining future water supply and use. For example, during the past few years major studies have been initiated in the Oldman River basin in southern Alberta, the Souris River basin in Saskatchewan and Manitoba, and the Mackenzie River basin in the north.

A great deal is known about quantities of water in the Saskatchewan-Nelson basin, but the data regarding ground water, water quality, and the supply of water in the north are limited. In addition, the impact of natural processes such as ground water discharge and recharge, erosion and sedimentation, and eutrophication is not well documented. Just how much effort should now be expended to increase our knowledge in these areas is a question which western Canadians and their governments need to address.

Demand for Water

Our analysis indicates that in certain western Canadian river basins water supplies at times place limitations on the extent to which existing demands can be met. Table 1 illustrates that most of these limitations are found in the southern prairie region. The data in Table 2 place the various demands for water within the Study Region in perspective, and indicate why demand in basins with large irrigation projects sometimes exceeds supply.

TABLE 1. SUMMARY OF OFFSTREAM WATER USE LIMITATIONS, BY BASIN AND BY USE

BASIN	IRRIGATION	OTHER AGRICULTURAL	INDUSTRIAL	MUNICIPAL	POWER GENERATION (THERMAL)
OLDMAN	L	L	--	L	--
BOW	L	L	--	N	FL
RED DEER	L	L	FL	N	FL
SOUTH SASK.	PL[1]	PL[2]	N	N	N
NORTH SASK.	PL[2]	PL[2]	N	PL[2]	N
SASKATCHEWAN	--	PL	--	--	N
QU'APPELLE	FL	L	FL	FL	FL
ASSINIBOINE	FL	PL	--	N	PL[4]
RED R./L.WPG.	--	PL	N	L	--
NELSON	--	--	--	--	--
CHURCHILL	--	--	FPL[3]	--	--
OTHER HUDSON BAY	--	--	--	--	--
MISSOURI	L	L	--	--	--
ATHABASCA	--	N	N	N	N
PEACE	--	PL	N	N	N
SLAVE/MACKENZIE	--	--	--	--	--
OTHER ARCTIC	--	--	--	--	--

L - LIMITED DURING LOW-FLOW PERIODS.
P - IN A PORTION OF THE BASIN.
F - IN THE FORESEEABLE FUTURE.
N - NOT LIMITED IN FORESEEABLE FUTURE
- - NOT A LIKELY SIGNIFICANT USE

1. ABOVE LAKE DIEFENBAKER.
2. BATTLE RIVER AND OTHER SMALL TRIBUTARY BASINS.
3. BEAVER RIVER BASIN.
4. SOURIS RIVER BASIN.

==

TABLE 2. SUMMARY OF PRESENT AND FORESEEABLE WATER NEEDS BY OFFSTREAM USES

OFFSTREAM USE	WITHDRAWAL (CONSUMPTION) - M^3/S*		
	PRESENT	FORESEEABLE	
		PLAUSIBLE**	EXTREME***
IRRIGATION	65 (50)	130 (100)	445-510 (355-410)
MUNICIPAL	20 (3.5)	30 (5.5)	40 (7)
THERMAL POWER	5.5 (2.7)	12 (6)	18 (9)
OIL SANDS	2.5 (1.5)	12 (10)	20 (18)
OTHER INDUSTRIES	7.5 (3)	15 (6)	30 (12)

* MEAN ANNUAL VALUES

** YEAR 2000

*** - COMPLETE IRRIGATION DEVELOPMENT OF 7-8 MILLION ACRES
- DOUBLING OF PRESENT POPULATION
- DEVELOPMENT OF ALL FORESEEABLE THERMAL POWER SITES
- DEVELOPMENT OF TOTAL OF BETWEEN 2 AND 2.5 MILLION BARRELS/DAY FROM OIL SANDS PLANTS
- QUADRUPLING OF PRESENT INDUSTRIAL USE, RELATING TO EXPANDED RESOURCE DEVELOPMENT

There are basically two ways in which we use water. The first, termed "offstream", withdraws water from streams or lakes and returns the portion not consumed (eg., irrigation, industrial, municipal). The second, "instream", does not withdraw water from rivers or lakes, but as the name implies, deals with instream uses such as fishing, recreation, transportation, and hydro-electric production.

Offstream Uses

Irrigation is the largest consumer of water in the region studied. Almost 1.5 million acres are presently developed for irrigation, about 3 percent of total cropland. As Table 3 indicates, most irrigation is located in southern Alberta. Project development is increasing in Saskatchewan, and there has been a recent heightened interest in Manitoba.

Irrigated lands generally produce much higher yields than do lands not irrigated. Three factors that are encouraging further irrigation are: probable increases in world demands for and prices of grain, a desire to maintain food self-sufficiency in Canada, and improvements in irrigation technology. A significant two-fold expansion of irrigated lands is possible in the three prairie provinces if improvements and additions are made to local storage and conveyance facilities. Provincial funds have been

Table 3. ACREAGES DEVELOPED FOR IRRIGATION, BY PROVINCE (1981)

PROVINCE	BASIN	ACRES	
Saskatchewan	S. Saskatchewan	108,100	
	N. Saskatchewan	7,400+	
	Qu'Appelle	10,500+	
	Assiniboine	4,150	
	Saskatchewan	300	
	Missouri	63,200	
	Total		193,650+
Alberta✓	Oldman	606,200	
	Bow	482,000	
	Red Deer	32,600	
	S. Saskatchewan	28,500	
	N. Saskatchewan	16,600	
	Missouri	25,600	
	Total		1,191,500
Manitoba	Assiniboine	8,000±	
	Red/Lake Winnipeg	5,000±	
	Total		13,000±

approved for major irrigation works improvements in southern Alberta. Federal-provincial studies underway in Saskatchewan and Manitoba could result in increased storage and conveyance works for use of South Saskatchewan, Souris, and Assiniboine River waters in those provinces.

Several studies have been made recently to determine the amount of land that could be irrigated if water were available. A seven or eight-fold increase has been estimated. The water available in several basins is not nearly adequate to supply the most generous of these estimates. This is particularly true in the dry regions of southern Alberta and southwestern Saskatchewan. For example, in one study of irrigable acreages, water requirements for areas that would rely on the Red Deer, Oldman, and Bow Rivers supply are estimated to be two to three times the water available in those rivers in a dry year.

The engineering feasibility of transferring water to these areas from northern rivers has been demonstrated. It has not yet been shown that such measures could be justified on economic grounds, or that the environment could be adequately protected. Transfers of water from the north to the south have also been linked to the possible export of water to the United States, where water shortages have reached critical proportions in some areas. The governments of Canada, Saskatchewan, and Alberta are opposed to water export, and there is no indication that the United States is officially interested in importing Canadian water.

In addition to irrigation, farmers and ranchers require water for stockwatering and domestic use, often in upland areas away from streams and lakes. Water sources include wells, dugouts, and irrigation canals, or rivers and lakes if nearby. Problems of unreliable supply and poor water quality are widespread on the southern plains. In dry years, both these problems can become severe, and they are not easily addressed because of the costs of transporting water to remote locations. While much of each problem is due to natural causes, agricultural practices also contribute. The increasing use of chemicals, poor waste disposal practices, and short-sighted drainage measures can add to the water woes of prairie farmers and ranchers.

The availability of an adequate water supply for stock watering is not often cited as a major factor in cattle production trends, although rangeland utilization in certain dry areas is limited by a lack of stock water. Economic factors, cattle raising technology, and the quality and quantity of pasture land are more apparent factors. If projected annual increases in herd sizes of four to five percent occur, water shortage may become more than just an accepted hardship.

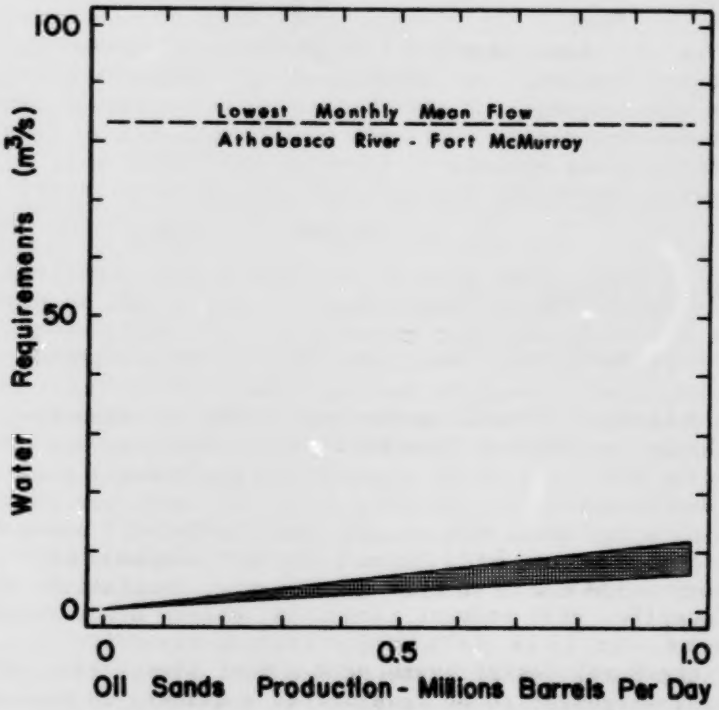
Municipal centres return large fractions of the water they withdraw and thus consume relatively little. They do, however, rely on assured supplies. Edmonton and Calgary are expected to increase in size dramatically, each reaching populations of one million by the early 1990s. Smaller growth rates are foreseen for Saskatoon, Winnipeg, and Regina. These cities will all continue to be adequately supplied with water, although Regina and Winnipeg will require expansions to their supplies, which come from distant sources. Lethbridge and Medicine Hat, located on rivers used extensively by upstream irrigation, will continue to rely on flows regulated to meet their needs.

Some smaller municipal centres that rely on supply from intermittent streams experience water supply problems in dry years, and are very vulnerable to drought conditions. Examples are plentiful in the southern basins, and even in areas of higher precipitation, such as in the Peace River basin. Some communities relying on ground water supplies also have problems in dry years, due to drying up of shallow aquifers.

Industrial water needs in the region are widespread. Mining and forestry sites are located in remote areas, but many small industries and petrochemical complexes are locating near large cities. Although some industries consume a high percentage of water required, the total impact of industrial uses on supply is not large. Potash, uranium, and coal mining will all expand and will not be limited by their water needs. Expected expansion of pulp mill operations in Alberta will also be adequately supplied with water. Increased refinery and petrochemical plants will locate near Edmonton and other Alberta centres. In most cases of industrial use, strict measures will need to be enforced to prevent individual and cumulative effects that could directly pollute water systems. The disposal of wastes too hazardous to discharge to lakes and rivers is an emerging concern. Considerable work is needed to ensure that surface, underground, and other disposal practices do not endanger natural water systems, including ground waters.

Oil sands plants are expected to consume large volumes of water. In this early stage of oil sands development, water uses are not yet large. Future expansions, though difficult to estimate accurately, could require substantial volumes of water. In the Cold Lake area, it is clear that expansion will require importation of water from other basins and strict measures to avoid pollution by waste waters. There will probably be a fully adequate supply of water for plants in the Athabasca oil sands region (Figure 4) but there may be problems of handling contaminated waste waters and large volumes of saline water pumped from the mines. Development of the Peace River oil sands has not been as thoroughly examined, and no specific water problems have yet been identified for any modest amount of production. Heavy oil operations presently require much less water. Nevertheless, some enhanced oil recovery operations in Saskatchewan, in the dry region between the North and South Saskatchewan Rivers, could encounter supply difficulties.

Figure 4. RANGE OF ESTIMATED WATER WITHDRAWAL REQUIREMENTS FOR APPROXIMATELY SEVEN ATHABASCA OIL SANDS PLANTS THE SIZE OF SYNCRUDE.



In thermal power production, generators are driven by steam and water is used for cooling. Thermal power plays a very small role in Manitoba (Table 4), where hydro power dominates. In Saskatchewan, about 75 percent of total power generated is thermal. Plants exist where coal supplies are accessible, but water supplies are low. Significant expansion in those areas is unlikely.

TABLE 4. SUMMARY OF THERMAL POWER DEVELOPMENT
(MEGAWATTS)

PROV./TERR.	BASIN	PRESENT	PROBABLE IN NEAR FUTURE	OTHER POTENTIAL DEVELOPMENTS
SASKATCHEWAN	ASSINIBOINE (SOURIS)	940	---	---
	S. SASKATCHEWAN	340	---	---
	MISSOURI	300	300	600
	OTHER	115	1200 *	
MANITOBA	RED/L. WINNIPEG	132	---	---
	ASSINIBOINE	237	---	---
ALBERTA	N. SASKATCHEWAN	3700	2250	5250
	BATTLE	750		
	PEACE	150		
	S. SASKATCHEWAN	170		
	RED DEER	---	750	2250
	ATHABASCA	---	---	3750
	BOW	---	---	2500
	OTHER	40		
TOTAL		6825	4500	14350

*BASIN NOT YET DETERMINED

In Alberta, thermal power production is extensive, growing, and likely to expand further. Eighty-five percent of the 5700 megawatts now produced in Alberta is from thermal plants. Sites under development or proposed would increase thermal power production by 3000 megawatts, and potential sites have been identified for an additional 14 000 megawatts. In some locations, like the Battle River basin, limitations due to low water supplies will prevent expansion, unless other water sources are found. In this particular case, a diversion of water from either the North Saskatchewan or Red Deer Rivers is considered by Alberta Environment to be feasible as a measure to enable thermal power expansion.

Instream Uses

Commercial fishing; sports fishing and other recreation; subsistence hunting, fishing, and trapping; hydro power production; and water-borne transportation are uses that do not directly withdraw water from river and lakes. Water in its natural setting also can be aesthetically important, and its presence is vital to other parts of the environment.

Commercial fishing is a steady or declining industry in parts of the region studied. Though problems exist with the quantity and quality of stocks in some places, the industry is also affected by economic factors and a loss of participants to other enterprises.

In Alberta, Lesser Slave Lake is the most productive of the 120 lakes fished. Catches in 1980 in Alberta reached about two million kilograms, worth $1.5 million. Some fish stocks in the northern drainage systems are affected by a parasite infestation which is not a problem in southern systems.

Saskatchewan's commercial fishery has been the subject of considerable concern. It is expected that the next decade could see severe overharvesting. A future loss of suitable habitat, especially in the north, is seen as a possible consequence of acid rain from industrial activity in Alberta and Manitoba. The 1979-80 catch totalled over five million kilograms, worth almost $4 million.

In Manitoba, most commercial fishing takes place in the very large lakes of the province. These fisheries are considered to be severely threatened by the proposed Garrison Diversion in North Dakota, which could permit the transfer of fish disease, parasites, and undesirable species of fish to Manitoba waters. In 1977, the International Joint Commission estimated that this diversion would essentially eliminate the fishery, resulting in an annual loss of about $6 million.

Although Great Slave Lake has a relatively large commercial fishery, the industry is not a major part of the economy of the Northwest Territories. It is variable and shows no sign of growth.

With rapid growth in the population of western Canada, and a trend toward increased leisure time, water-based recreation will continue to grow. It is not, however, given a high priority in water allocation decision-making. For example, in Alberta it ranks last with "other uses", even though tourism is the third largest industry in the province.

In Saskatchewan, an indication of the economic importance of sports fishing is its comparison with commercial fishing. As far back as 1975, the recreational fishery in Saskatchewan was estimated to be worth about $137 million to the province. As a measure of growth, it is expected that active anglers will almost double between 1979 and 1990 in that province.

In all the provinces and the territories, previously inaccessible areas are now being opened up by resource development. Although transportation costs may become an inhibiting factor, there is every indication that these areas will become increasingly used for recreation.

Competition with other uses will increase. Water quality and low-flow conditions are already a serious concern in parts of the Saskatchewan-Nelson system. The presence of mercury and biocides, and the effects of over-enrichment and acid rain in some waters of the region studied, are all threats to fish. Deterioration of lakes due to algae and weed growth is a widespread annoyance, though in many cases causes are natural, and difficult to deal with.

Waterfowl conservation and production are also in conflict with other land and water uses. Ducks Unlimited and government agencies fund numerous habitat programs, especially in the southern parts of the plains. Nevertheless, there is concern that drainage of wetlands, increased usage of biocides, and certain tillage practices will continue to reduce the habitat necessary for waterfowl and other wildlife. In Saskatchewan, over two-thirds of the duck breeding area is under cultivation, causing inevitable conflict. Although many positive steps have been taken by private groups and government agencies, there is concern that the present trend could result in a critical loss of habitat.

The protection of "wild" rivers, as part of the natural heritage, and as sources of recreation, continues to be urged by conservation and wilderness groups. With the construction of dams on the Red Deer and Oldman Rivers and possibly on the Liard River in the foreseeable future, the flows of almost every major river in the provinces of the Study Region will be altered, or "regulated". This concern is felt most keenly in the high-use recreation areas of mountain rivers. In rivers rising on the plains, regulation can benefit recreation by providing more reliable flows. Some artificial reservoirs provide popular centres for water-based recreation.

The region studied is rich in natural waterways of scenic and historic value. These can be found in many varied settings. The valley of the Souris River in Saskatchewan has stretches considered to be unique. The waterways of northern Manitoba have long been prized for their historic value.

The awesome beauty of the waterways in Nahanni National Park in the Northwest Territories has been of considerable public interest. This area, and many others of aesthetic value, have been set aside for protection by federal, provincial and territorial governments. There are disagreements about the degree to which protection can or should be enforced in these areas, and about the quantities of land that should be protected from development.

Subsistence hunting, fishing, and trapping, mainly by native peoples, have a close relationship to water quantity and quality. Though more commonly practised in the far north, these subsistence uses are also important to scattered groups in the south where they occasionally come into confict with other water uses. The rights of native peoples, part of the orderly development of water resources, have not always been adequately observed.

There are several examples of major disturbances or threats of disturbance to water systems that affect subsistence activities:

- extensive damage (now repaired) to the Peace-Athabasca delta (1967)
- damming and diversion of Southern Indian Lake, Manitoba, resulting in effects on fishery and water quality
- possible conflicts with hydro and agriculture uses in deltas of the Saskatchewan River
- threat to subsistence fisheries in Lake Winnipeg and Lake Manitoba by the proposed Garrison Diversion.

An example of a successful resistance by native peoples to a development that threatened subsistence uses is the case of the once proposed Churchill River hydro development in northern Saskatchewan. Increasingly, native groups are expressing their wish to participate in water planning. In some southern basins, their water planning interests include agricultural, municipal, recreational, commercial fishery, and cultural, as well as subsistence, water uses.

Hydro power has been extensively developed in the region studied (Table 5). Most of this development is in Manitoba (3650 MW) and British Columbia (3100 MW), with lesser amounts in Saskatchewan (575 MW), Alberta (800 MW), and the Northwest Territories (50 MW).

TABLE 5. SUMMARY OF HYDRO-ELECTRIC POWER DEVELOPMENT
(MEGAWATTS)

PROVINCE	RIVER	PRESENT	PROBABLE IN NEAR FUTURE	OTHER POTENTIAL DEVELOPMENTS
SASKATCHEWAN	S. SASKATCHEWAN	187		
	SASKATCHEWAN	280	250	600
	CHURCHILL	107		
MANITOBA	WINNIPEG	560		
	SASKATCHEWAN	472		
	NELSON	2602	2470	3310
	BURNTWOOD		750	
	CHURCHILL			250
ALBERTA	BOW	325		
	N. SASKATCHEWAN	475		
	PEACE		1000	
	SLAVE			1800
BRITISH COLUMBIA	PEACE	3116	900	
	LIARD			4000 - 5000
N.W.T.	VARIOUS	48		
TOTAL		8177	5370	10 000 +

A surplus of hydro power in Manitoba, and additional foreseeable sites there totalling 3200 MW, are an important component of a proposed Western Power Grid. If approved, the Grid would delay some hydro and thermal projects in other provinces.

Major proposed hydro sites on the Peace River (Site C in British Columbia and Dunvegan in Alberta) are not expected to encounter major opposition, although some environmental concerns exist. There is perhaps a stronger opposition using economic arguments that disagree with the immediate need for large hydro expansions.

Another major development (1800 MW) on the Slave River appears to be more environmentally contentious. Impact studies have yet to be conducted and the extent of possible opposition is hard to assess at present.

All these new projects, as well as one approved site (250 MW) and two probable sites on the Saskatchewan River (600 MW), are "run-of-the-river" developments, which would not cause large changes to river flows. Possible development of the Liard River could have much more significant effects. Sites have been identified on the Liard totalling 5000 MW. The river is presently unregulated and is the site of a provincial park and native lands, which could be affected. Downstream, the present annual flow cycle plays important roles in ice breakup and climate factors in the Mackenzie River valley. Power dams on the Liard would substantially change the flow pattern; and the effects on climate, the hydrology of the Mackenzie, and the ecology of the Mackenzie delta will require evaluation.

Although ferries, and freight and passenger vessels, operate on only a small scale in the provinces, river and lake transport continues to be important on the Mackenzie River system. Highway and railway development may eventually replace much of this activity, but for the foreseeable future it is expected to continue to play an important role in the north.

River flow is a crucial factor for river transport. High flows are restrictive because they cause difficult navigation conditions in rough waters, but low flows can bring river shipping to a halt. In 1980 and 1981, low Mackenzie River levels severely hampered late season shipping. River regulation can benefit transportation by smoothing out seasonal extremes in water levels. Any project that significantly reduces water levels could be detrimental. No effects of that type have yet been predicted for proposed projects in the Mackenzie River system.

Major Supply/Demand Issues

Transportation, hydro power development, some resource development, and subsistence applications are the main water uses in the northern basins. These are predominantly instream uses, dependent upon reliable annual flows throughout the system. In the southern basins, offstream uses for irrigation, municipalities, industry, and thermal power plants are far more significant. In these cases, the total water available for consumption is of more interest.

Water tends to be treated as a free good, and there is considerable waste in the use of water, even in water-short areas. Water is lost in transport to users and efficiency in use is often very low. Rationing, pricing, and scheduling of water use are mechanisms that could affect demand. With appropiate incentives, the total demand for water can be reduced by increased recycling, employment of technologies that require less water, and elimination of some uses altogether. Progress is being made, but waste is much more prevalent than in the use of other, more costly resources.

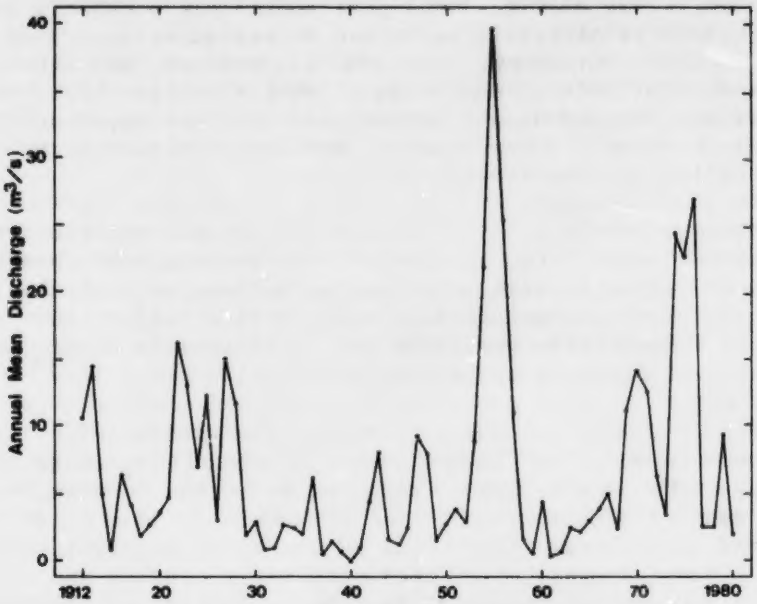
Planning for future water use requires, among many other things, reasonable forecasts of future water demands, particularly for users of large quantities of water.

The demand for water is tied to a large number of other variables and is usually difficult to predict with precision. In western Canada estimates of demand for irrigation water, for example, vary considerably based upon widely divergent interpretations of the amount of irrigable land. This is but one example that illustrates the need for greater accuracy in forecasting.

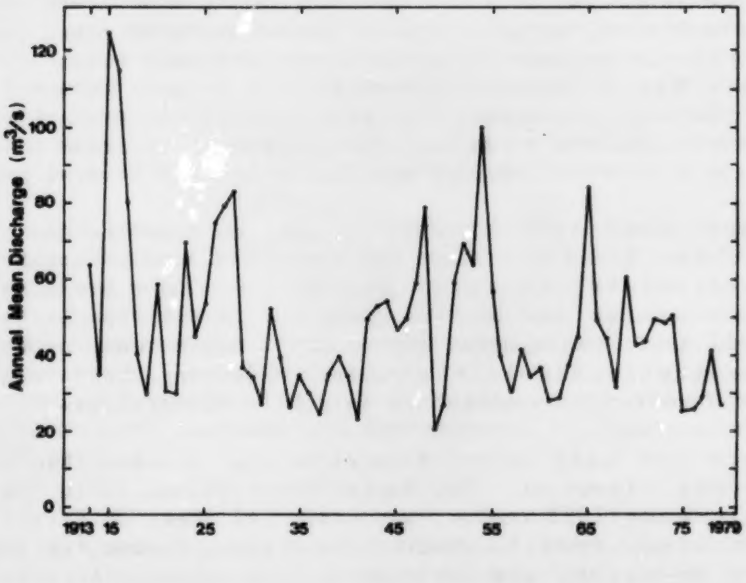
When natural supplies of water are at moderate to high levels for a number of years, there can be a tendency to expand developments that are water dependent. Realistic planning requires that low supply conditions must be expected to occur from time to time. The drought conditions of the late thirties have not been forgotten. As recently as 1977, the spectre of drought again arose. Very low supply conditions demonstrated that water uses had expanded to an extent that a prolonged "thirties" drought could be devastating, despite major programs to store and divert waters. The 1977 drought proved to be costly in terms of hydro power reductions and agricultural losses.

The water supply conditions of the 1930s and 1977 are included in Figure 5, which illustrates the variability of supply over a long period in this region. When major rivers are very low, the drought situation is called a "hydrologic" drought and affects all instream and offstream users. This is usually due to poor snow storage conditions in the mountain regions. When precipitation on the land is low, an "agricultural" drought occurs, with greater impact on dryland agriculture and forested areas. When both occur together, the worst droughts ensue.

Figure 5. EXAMPLES OF LONG-TERM VARIABILITY OF ANNUAL NATURAL FLOWS OF: (a) the Qu'Appelle River near its mouth



(b) the Red Deer River at Red Deer



Many imaginative water management measures have been developed to offset the effects of drought. Saskatchewan and Manitoba, with the federal government, are presently studying further ways to protect present and future water uses from future dry periods. Measures already determined, and others being assessed, include local supply and storage improvements, identification of use limitations and/or opportunities for further economic development, and improvements to the general understanding of conservation practices.

Water transfer is often considered as a means of reducing drought vulnerability. Many small-scale transfers of water have already been made within basins, or between adjacent basins. A few major diversions have been made in this region, such as from the South Saskatchewan River to the Qu'Appelle River, and from the Churchill River to the Nelson River.

In the first of these examples, the present effects on the donor basin are not large and the receiving basin benefits greatly. In the second example, there has been and still is great apprehension about the effects, because the volumes diverted are large fractions of the total supply in the donor river. Some negative effects to water quality and the local fishery have been reported, but the evaluation of the diversion is not yet complete.

Concern about possibly serious environmental and economic effects have resulted in delays or cancellation of other proposed diversions. A transfer of water from the Fraser River system to the Peace River (McGregor Diversion) was dropped because of the possibility of transferring parasites to the Peace River. A similar reason has stalled the proposed Garrison Diversion between the Missouri River and the Souris and Red Rivers.

Other diversions of water, such as from the Assiniboine River to the Red River basin and from the South Saskatchewan to the Souris River, are also possible. These projects would improve supplies for various uses. In Alberta, it has been mentioned that major works improvements are already approved to increase irrigation in the south. Major interbasin transfers have also received much attention in public discussions.

There are many other diversions that are feasible from an engineering viewpoint. The Saskatchewan-Nelson Basin Board, in its well-known 1972 report, has described these in detail. The possible diversions in Manitoba and Saskatchewan, as drought-proofing measures, are included in that report. Also included are possible routes for transferring water from northern Alberta to the south.

Opposition to major diversions is based mainly upon environmental and economic grounds. Damage to the Peace-Athabasca delta, when construction of the Bennett Dam reduced peak flows of the Peace River, is cited as an example of the effects of diminished flows in large northern rivers, even though a diversion was not involved. The effects of the Churchill-Nelson diversion on the Churchill River are also cited as an example of environmental damage due to a major diversion.

Economic arguments point to the enormous costs of dams, canals, and operating procedures. There is also the possibility of reduced water use options in donor river basins. Advocates of water transfers argue that agricultural development could realize great potentials which would be badly needed in future years. They also point out that water diversion requirements to supply substantial irrigation increases or improve supplies to other users are only small fractions of water now flowing in the north.

Clearly, both sides require considerable work to marshall their arguments. Decision makers will need sound advice from all quarters, if additional major transfers are to be given serious consideration.

Other Issues

Large volumes of ground water are present beneath the region studied, although detailed information is often not available. Substantial variability in quantity and quality can occur over short distances. Where flow rates and quality permit, ground water is used in a wide variety of applications: irrigation, municipal and industrial supply, stockwatering, farm domestic uses, oil field injection, and recreation. Ground water has even been used to make snow for a Saskatchewan ski resort.

Ground water use is not licensed in some parts of the region, and the extent of use is poorly known in other parts. However, a great deal of attention has been paid to it in Saskatchewan, Alberta, and parts of Manitoba. In some areas, like the Milk River basin, overuse and wastage have been identified. In other areas, opportunities for further usage are being evaluated. Examples include southwestern Manitoba (for irrigation) and southeastern Saskatchewan (to supplement thermal power plant needs).

The water quality of large ground water supplies is generally known, but detailed knowledge is lacking. What is even more poorly known is the degree to which ground waters can become polluted by wastes discharged down wells. This is an increasing practice and requires attention.

Not all precipitation drains readily from the land. In fact, some basins have very poor drainage systems, as indicated by the percentage of area that is effectively drained (Table 6). In the past, private projects to drain areas for agricultural use have sometimes caused problems. These include flooding other areas, loss of valuable bird and wildlife habitat, loss of local water supplies, and increased salinization of cropland. Recognition of the seriousness of these problems has led to stricter controls in all provinces.

TABLE 6. GROSS AND EFFECTIVE DRAINAGE AREA, BY BASIN (DREE, 1978B)

BASIN	GROSS DRAINAGE AREA (KM²)	EFFECTIVE DRAINAGE AREA (KM²)	PERCENT EFFECTIVE
OLDMAN	27 500	21 300	77
BOW	25 300	19 500	77
RED DEER	46 800	32 200	69
SOUTH SASK.[1]	50 000	16 300[2]	33
NORTH SASK.	135 000	74 000	55
SASKATCHEWAN[1]	78 000	71 400[2]	91
QU'APPELLE	50 800	17 000	33
ASSINIBOINE[1]	81 700	32 000[2]	39

1. NOT INCLUDING CONTRIBUTING BASINS UPSTREAM
2. ESTIMATED

Paradoxically, in a region so vulnerable to drought, flooding can also be a serious issue. Many dams and other flow control structures serve to regulate flood waters, though some only to a limited degree. The Assiniboine and Red Rivers have been extensively controlled, specifically for flood protection. Developments in many other basins remain at the mercy of the extremely high flows that can occur, even in small prairie rivers.

Flood damages in the many millions of dollars have occurred in this region. Each province has programs designed to determine flood-vulnerable areas, construct preventive works, and reduce damages. Federal-provincial programs of flood damage reduction have been implemented in Manitoba, Saskatchewan, and the Northwest Territories. Additional joint projects are being evaluated in conjunction with the drought-related projects mentioned earlier.

Ideally, water management and environmental protection should be compatible. But they may not be, and decision makers continually face conflicts between programs that serve a variety of water users, and programs designed to protect the environment. Our society requires a high level of orderly development of the resource, with "orderly" including recognition of environmental needs.

In addition to the recreational and aesthetic requirements of environmental protection, there is the aspect of respect for the integrity of other living fauna and flora. In the region studied, a number of these are threatened either locally or in terms of total extinction. The best known is the whooping crane, which nests in Wood Buffalo National Park. Other species are far less well known, including a species of snail in the Liard River. Of local importance is a colony of white pelicans which nest on an island in the Slave River. Though the species is not threatened with extinction, this colony is uniquely situated and could be threatened by proposed hydro development, just as the snail species could be threatened by Liard River hydro development.

Water Management

The provinces manage the waters within their jurisdictions. The federal government has certain responsibilities related to fish, navigable waters, interjurisdictional matters, northern waters, some aspects of economic development, and federal lands. In addition to their separate responsibilities, the three prairie provinces and the federal government have joined forces in the Prairie Provinces Water Board (PPWB) to oversee the reasonable apportionment of waters flowing eastward in the region studied. The PPWB is also evaluating interprovincial water quality needs and is preparing a comprehensive review of historical and present water uses.

No similar organization has yet been formed to oversee interjurisdictional concerns in the Mackenzie basin. In view of developing water uses in that region, a joint committee could perhaps evolve. A major study by all jurisdictions on the Mackenzie basin has recently been completed.

The number of government agencies dealing with water-related matters is large. There are different approaches among the several jurisdictions to the structure of organizations dealing with water. Some examples:

- federally, and in Alberta and Saskatchewan, fish and water are the reponsibilities of separate departments
- in Saskatchewan and Alberta, water-related recreation and water management are in separate departments
- in Manitoba, water quality and water quantity are managed by separate departments
- in the federal structure, no less than four separate departments have water-related responsibilities in the region studied: Environment, Fisheries and Oceans, Regional Economic Expansion (PFRA), and Indian and Northern Affairs.

Procedures for licensing water use and obtaining accurate information about supplies and quantities actually used vary from province to province. In many cases, procedures are complicated and data are almost impossible to find in convenient summaries.

There is, as yet, no clearly defined effort by the several jurisdictions to undertake joint, comprehensive, basin-wide water planning for the future. Two large interjurisdictional studies, on the verge of completion, will deal with water uses in the Mackenzie River basin, and in the basins of eastward flowing rivers, respectively. Although these reports could provide the bases for planning purposes neither study addresses the future.

Two provinces, Alberta and British Columbia, have established district offices with responsibilities related to specific basins. Alberta, in fact, has located specific basin planning staff in its districts.

Water management legislation in all of the western Canadaian jurisdictions has placed substantial discretionary water management powers in the hands of government managers or administrative agencies. Clearly, exercise of these powers affects private decision-making. In addition, there is a potential for a conflict of interest to arise when government acts as both developer and regulator.

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ACRONYMS

ACW - Advisory Committee on Water (Alberta)
AECA - Alberta Environment Conservation Authority
AENR - Alberta Energy and Natural Resources
AID - Aetna Irrigation District
ARDA - Agricultural and Rural Development Administration
BRID - Bow River Irrigation District
CTC - Canadian Transport Commission
DIAND - Department of Indian Affairs and Northern Development (Canada)
DINA - Department of Indian and Northern Affairs (Canada)
DMREM - Department of Mines, Resources, and Environmental Management (Manitoba)
DNS - Department of Northern Saskatchewan
DSS - Department of Supply and Services (Canada)
DREE - Department of Regional Economic Expansion
DU - Ducks Unlimited (Canada)
EC - Environment Canada
ECA - Environment Council of Alberta
EID - Eastern Irrigation District
EMR - Energy, Mines and Resources Canada
EPS - Environmental Protection Service (Environment Canada)
ERCB - Energy Resources Conservation Board (Alberta)
EUPC - Electric Utilities Planning Commission (Alberta)
FEC - Fisheries and Environment Canada
GNWT - Government of the Northwest Territories
GDU - Garrison Diversion Unit
IJC - International Joint Commission
IWD - Inland Waters Directorate (Environment Canada)
LID - Leavitt Irrigation District
LNID - Lethbridge Northern Irrigation District
MID - Magrath Irrigation District
MLM - MLM Ground-Water Engineering
MPTF - Major Projects Task Force
MVID - Mountain View Irrigation Districts
NCPC - Northern Canada Power Commission
NPA - Northern Pipeline Agency
NTCL - Northern Transportation Company Ltd.
ORSMC - Oldman River Study Management Committee
PFRA - Prairie Farm Rehabilitation Administration
PPWB - Prairie Provinces Water Board
PRCF - Petroleum Resources Communications Foundation
QBSB - Qu'Appelle Basin Study Board
QVIDA - Qu'Appelle Valley Indian Development Authority
RCID - Ross Creek Irrigation District
RID - Raymond Irrigation District

SMRID - St. Mary River Irrigation District
SNBB - Saskatchewan-Nelson Basin Board
SPC - Saskatchewan Power Commission
SRBSB - Souris River Basin Study Board
SSEWS - Saskatoon-Southeast Water Supply
SSRID - South Saskatchewan River Irrigation District (No. 1) (sometimes referred to as SSRIP)
STRR - Saskatchewan Department of Tourism and Renewable Resources
TID - Taber Irrigation District
UID - United Irrigation District
UMA - Underwood McLelland Ltd.
WER - W-E-R Engineering Ltd.
WID - Western Irrigation District
WUD - Water User District

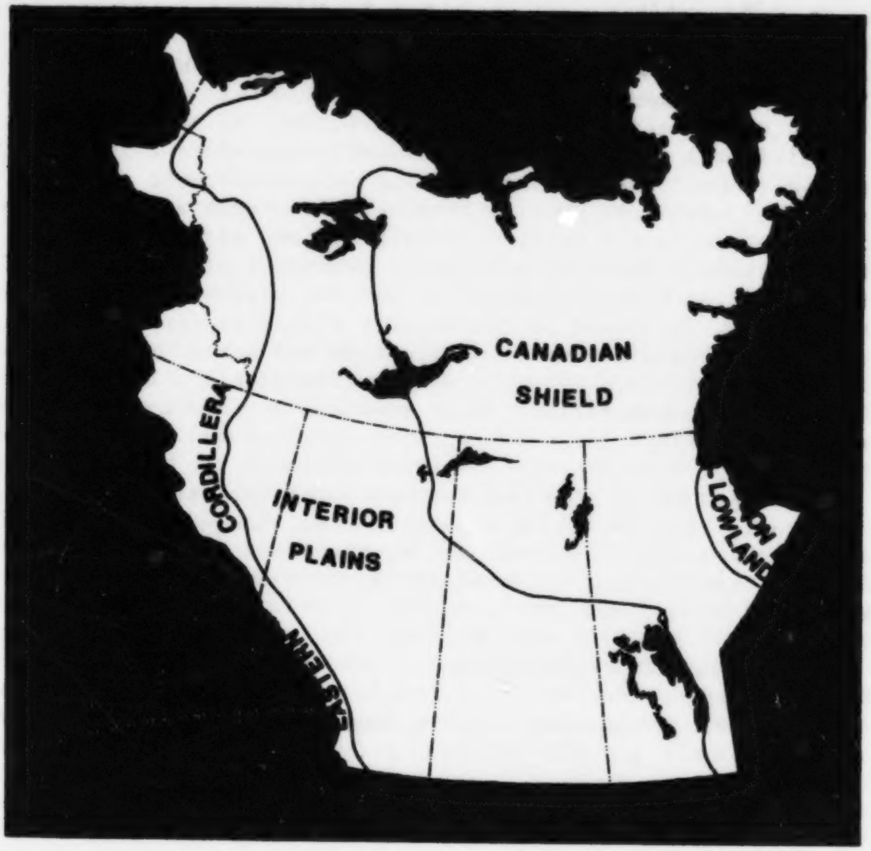
PART A.
THE STUDY REGION

CHAPTER I

CHARACTERISTICS OF THE STUDY REGION

1. PHYSICAL DESCRIPTION

Figure 6. PHYSIOGRAPHIC REGIONS OF THE STUDY REGION.



The Great Divide separates drainage to the Pacific Ocean from drainage to the regions included in this study. The land east of the Great Divide is commonly thought of as being a flat expanse of grasslands in the south and a large tract of forest and tundra in the north. The geography, in fact, is much more diverse, and the term "prairie provinces", used for describing Manitoba, Saskatchewan and Alberta, is really a misnomer. The major physiographic types (Figure 6), are the Eastern System of the Cordillera, the Interior Plains, the Canadian Shield, and the Hudson Bay Lowlands. Numerous soil, vegetation, and cultural zones are also located throughout the Study Region.

The Eastern Cordillera includes the eastern slopes of several mountain ranges and consists of a series of parallel mountain ridges and valleys aligned in a general northwest - southeast direction. The mountain ranges (for example, the Rocky Mountains) exhibit very sharp local relief, in many cases rising more than 2000 metres above the floors of the intervening valleys. The valleys, in turn, have been shaped primarily by glaciation and subsequent erosion.

Although the high mountain ridges produce a general "rain shadow effect" to the east, there is considerable precipitation in those parts of the mountains which drain eastward from the Cordillera. This relatively large amount of precipitation, and the substantial relief, combine to produce a high annual yield of water to rivers in the foothills and the plains beyond. The soil cover that is found on the steeper slopes is generally thin and coarse, allowing rapid infiltration and subsurface movement to streams. Although rivers draining from glaciers are turbid from finely ground materials, most mountain streams are clear and of excellent quality.

The Interior Plains region does not exhibit the general uniformity that the title implies. Even though the relief of the region as a whole is very gentle, there are several hilly areas, such as the Cypress Hills and Swan Hills in Alberta and the Duck Mountains in Manitoba.

The Plains are in fact a series of three steps beginning with the Manitoba Plain in the east, which extends from the Canadian Shield westward to the Manitoba Escarpment. The second level extends to the Missouri Coteau and the third to the foothills. In Manitoba and Saskatchewan, the Plains region is bordered on the north by the Canadian Shield, but farther west it extends in a narrow band to the Beaufort Sea.

The general slope of the Interior Plains is from southwest to northeast. Soils range from the Brown, Dark Brown, Black, and Dark Grey soil groups in the southern areas, to podzols in the wetter regions, which also contain widespread organic soils in muskeg. In the north, there are extensive permafrost areas.

There is a gradual transition of vegetation groups from south to north. The grasslands of the warmer and drier southern portions of the plains give way to a mixed grass prairie of denser, taller, and more diverse grass as one moves northward. The northern portion of the plains contains a parkland zone in which a mixture of grassland and woodland cover is found.

The parkland zone blends northward to a mixed forest region containing large quantities of both coniferous and deciduous trees. From the mixed forest region, the northern transition to the tundra has a more open, park-like, and somewhat stunted forest growth.

Much of the streamflow available to the Interior Plains rises in the mountains. Water added from drainage in the Interior Plains is limited because of low precipitation and high evaporation and transpiration. The soils in the Plains have large soil moisture storage capacities, which can affect the timing of drainage to rivers after periods of rain. The quality of rivers arising on the Plains is quite variable, but because erosion is high, the waters usually are high in dissolved and suspended solids.

The Canadian Shield is the major physiographic feature of the Northwest Territories and the northern portions of the prairie provinces. Erosion by water and ice has left a landform composed of extremely hard, erosion-resistant rock. The region is characterized by numerous angular lakes and marshy depressions, and a poorly organized drainage system.

The Canadian Shield has a very large surface water resource in its numerous lakes and marshes. The area has a very high yield relative to precipitation, and the streams have a more seasonally balanced flow pattern than those in the Cordillera because of the large natural storage in lakes. The quality of the water is good in terms of dissolved and suspended solids, although some relatively high mineral and organic concentrations are found.

The Hudson Bay Lowlands consist of flat muskeg plains dotted with shallow lakes, interrupted by raised gravel beaches. Surface materials are more easily eroded than in the Canadian Shield, so that dissolved and suspended solids contents are higher.

2. CLIMATE

The water resources of any region are strongly influenced by its climate. Temperature affects the occurrence of snow and ice and also influences evaporation and water quality. Precipitation is a major part of the natural cycle of water, the hydrologic cycle, which is discussed in the appendix.

The coldest month of the year in this region is January (Figure 7). Mean daily air temperature values of -7.5°C are found southwest of Lethbridge on the Alberta-Montana border. Northeastward, the values decrease to -35°C in the northern portion of the District of Keewatin.

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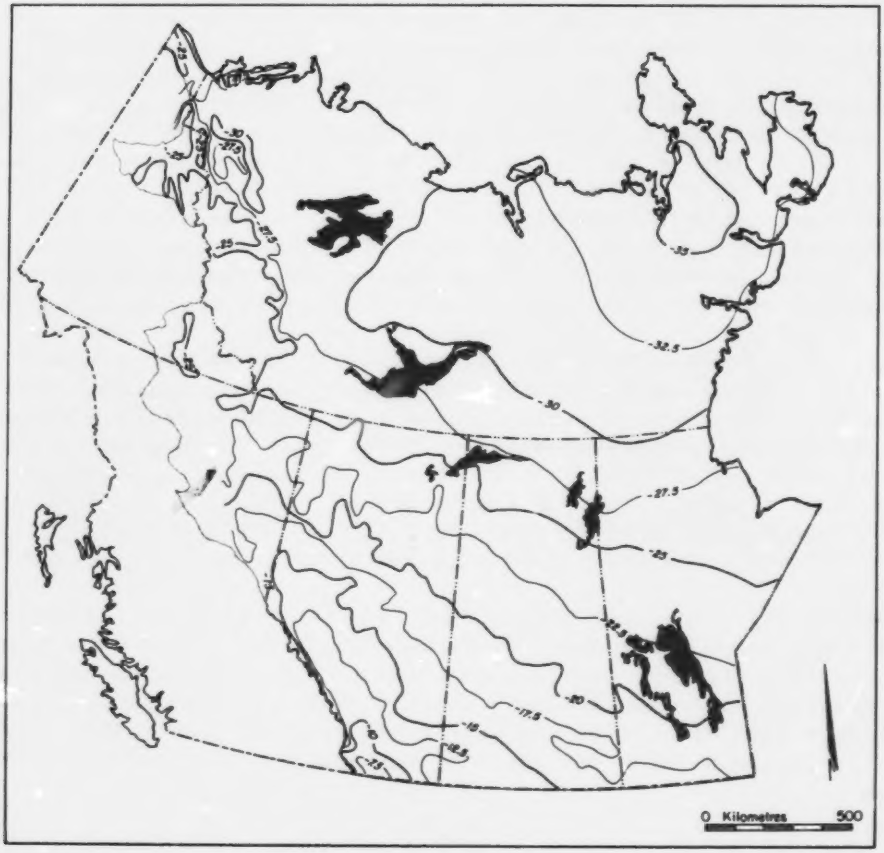
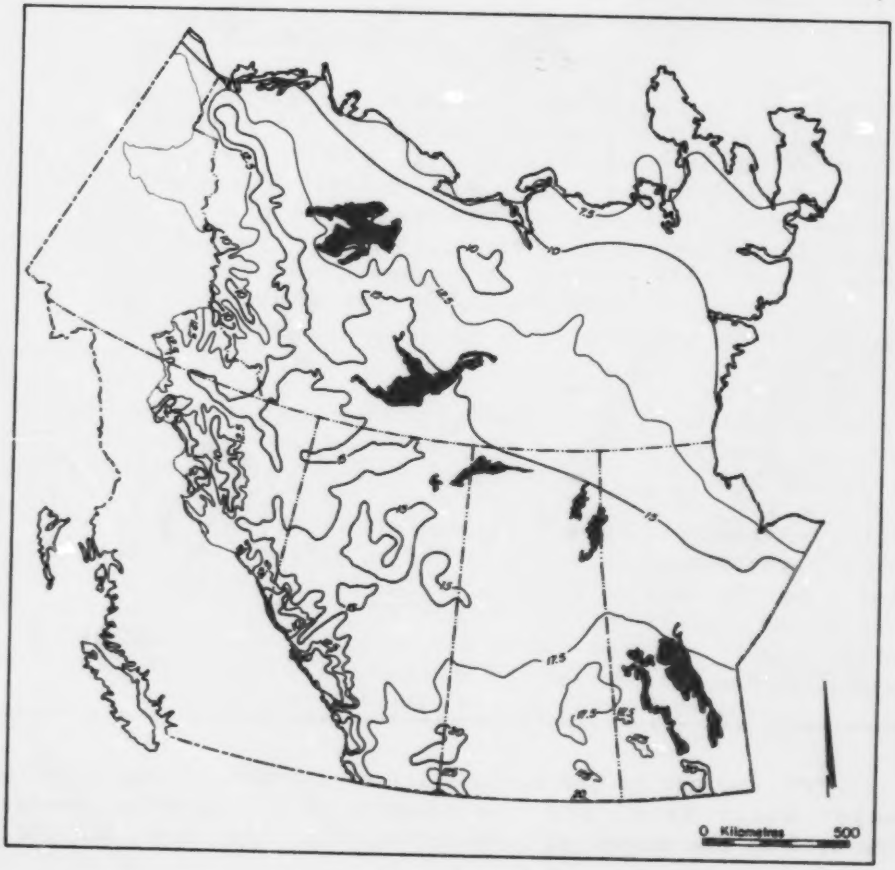
Figure 7. MEAN DAILY AIR TEMPERATURE (°C) - JANUARY.



In general, the Study Region experiences long, cold winters. Typically, a winter ridge of high pressure develops between low pressure areas over the Gulf of Alaska. This extends to the region south of Hudson Bay in the east, bringing much of the clear cold weather to western Canada.

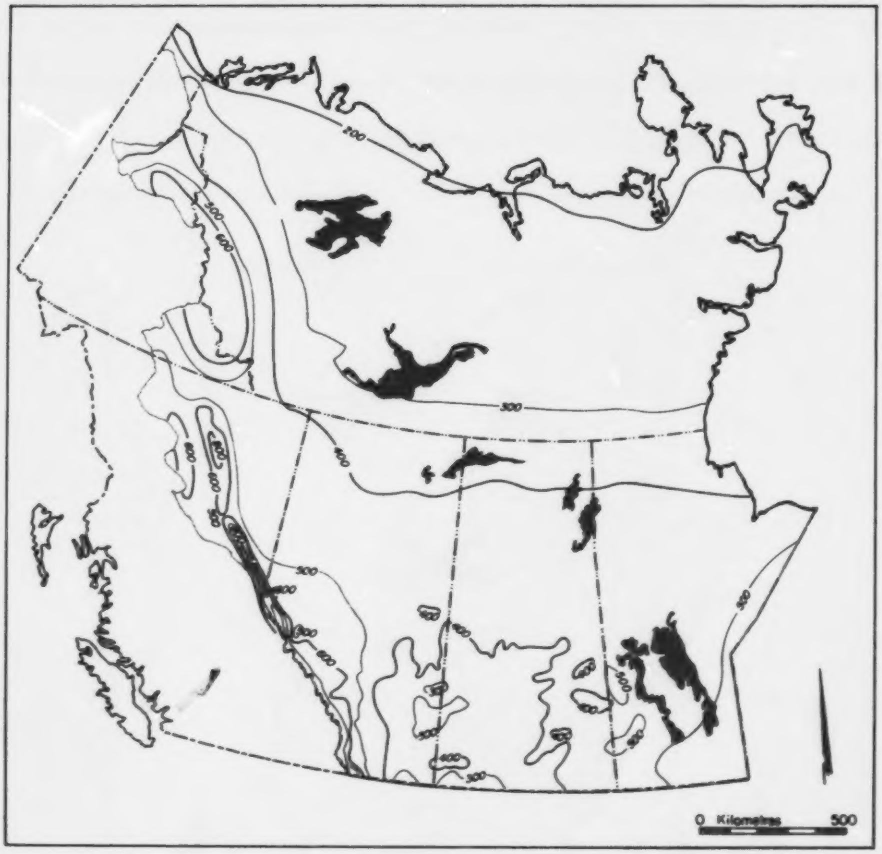
The higher mean temperature values in the southwest, particularly in Alberta, are partly due to foehn winds (locally called chinooks). These warm, dry winds have both beneficial and harmful effects. They provide a respite from the severe cold and reduce the snow cover in southern Alberta so that cattle may feed throughout the winter. However, by reducing the snow cover, chinooks also reduce the amount of soil moisture available and may significantly reduce subsequent spring runoff.

Figure 8. MEAN DAILY AIR TEMPERATURE (^{o}C) - JULY.



The mean daily temperature for July, the warmest month of the year, is shown in (Figure 8). Highest mean values range from 17.5°C to 20°C along the boundary with the United States, while lowest mean values of 5°C to 7.5°C are found along the north shore of the Northwest Territories. The Medicine Hat region in Alberta and the region south of Winnipeg are the warmest areas in July within the Study Region.

Figure 9. MEAN ANNUAL PRECIPITATION.



Two indices of the suitability of climate for agriculture, a major water user, are the length of the growing season, as measured by the number of consecutive frost-free days, and the heat supply. The frost-free period in the southern portion of the study area is approximately 120 days. The northern and western fringes of widespread agricultural activity are in areas with 60-70 frost-free days.

The heat supply available is largest in the Medicine Hat area of Alberta and the Morden area of Manitoba. The longer periods of daylight in the north during the summer months to some degree moderate the lower intensity of the sun's radiation in that region.

The mean annual precipitation patterns of western Canada are illustrated in Figure 9. Except for the Cordillera region, most of the area is relatively dry, with a range of annual precipitation values of from 200 mm to 500 mm.

A large, particularly dry area exists in southeastern Alberta and southwestern Saskatchewan. Because the annual precipitation averages between 300 mm and 400 mm, extensive grazing and irrigation farming were the predominant agricultural practices in this area.

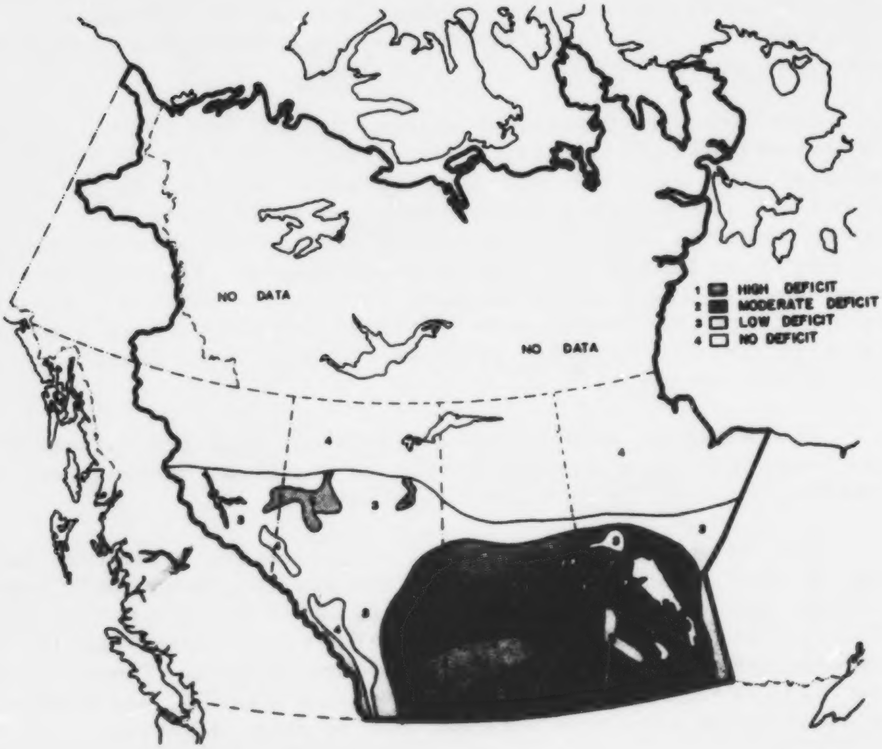
The relative dryness of western Canada east of the foothills is caused mainly by the rain-shadow effect of the Rocky Mountains. Most of the precipitation received on the western parts of the plains regions comes from moist Pacific air masses. South-central and southeastern portions of Manitoba are more strongly affected by southern air masses. The Pacific storms lose most of their moisture prior to reaching Alberta. If summer rains from the south are relatively abundant, very good crops usually result. However, if these are limited or absent, drought conditions can occur.

The mountain areas receive relatively high precipitation and may even receive much more than is measured, because recording stations are usually in valley locations.

The other major source of precipitation in western Canada are storms that develop on hot days due to convection. Longley (1972) has estimated that up to 40 percent of the annual precipitation received in the Interior Plains results from convectional cooling during the summer months. Thunder storms and hail frequently accompany these events, and associated rainfall is usually very intense, but of short duration.

Although spring and summer rains account for a large proportion of the annual precipitation, much of it is used to replace the soil moisture and ground water losses that occur during the summer (Figure 10.). Because of this, very little of the precipitation received during the summer finds its way to local streams. Snowmelt in the eastern slopes of the Cordillera provides the greater part of the runoff that flows to the plains, and is very important to the total supply. Local plains runoff is derived mainly from snowmelt and provides a smaller source of supply.

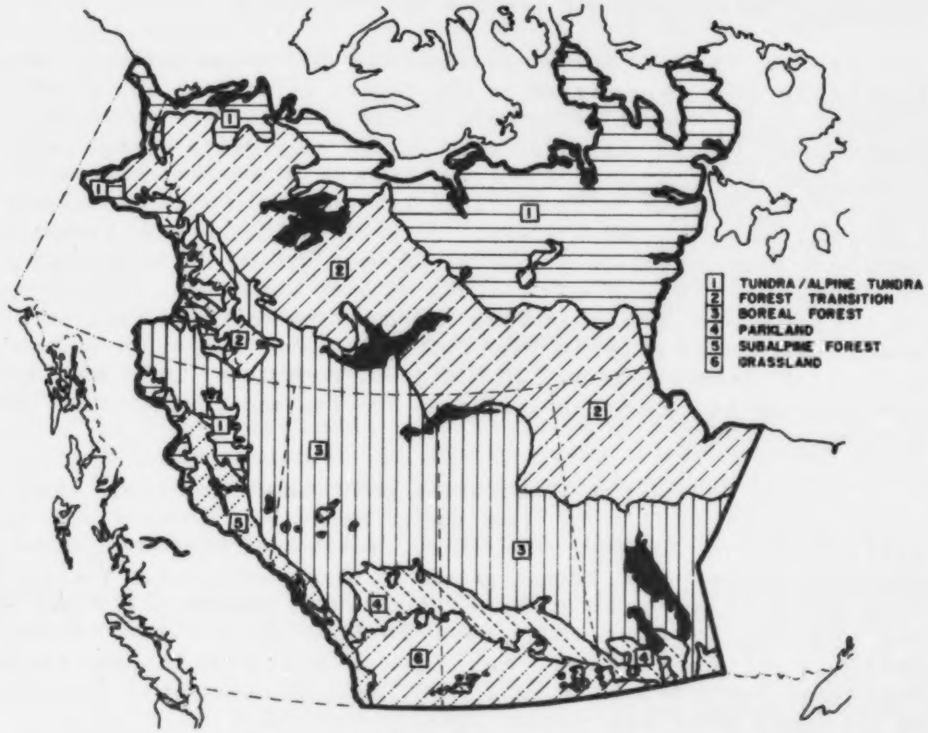
Figure 10. SOIL MOISTURE DEFICIENCIES (DREE, 1978a).


NO DATA
NO DATA
1 HIGH DEFICIT
2 MODERATE DEFICIT
3 LOW DEFICIT
4 NO DEFICIT
4
4
3
3
3
3

3. Natural Resources

The Study Region is rich in natural resources. Some form the basis for economic development, while others are valued as components of the natural environment. In the development or enjoyment of these resources, water is often a principal supporting factor.

Figure 11. VEGETATION ZONES (Environment Canada, 1979b).


1 TUNDRA / ALPINE TUNDRA
2 FOREST TRANSITION
3 BOREAL FOREST
4 PARKLAND
5 SUBALPINE FOREST
6 GRASSLAND
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6

Soils and Forests

Two of the basic natural resources in the Study Region are its soils and its forests. They provide a basis for social, political, and economic development, and consequently have been transformed considerably by human activities. Vegetation patterns have strong relationships to water resources and so are described in some detail.

Mixed and coniferous forests form a broad band across the region, extending from Lake Winnipeg to northeastern British Columbia (Figure 11). This Boreal Forest also extends upstream along the Liard River to the mountains in the Yukon Territory and downstream along the Mackenzie River in the Northwest Territories. Subalpine and montane forests are located in the mountains from the Liard River south to the Alberta-Montana border.

These forests sustain a number of commercial forestry operations, provide important wildlife habitat, and support considerable recreation activity. In the foothills and mountains particularly, the forests influence the amount, timing, and quality of water yield and provide soil stability.

By far the greatest percentage of commercial timber available for production in the region is in British Columbia. Present development is centred around pulp and saw mills in the Peace River basin. In Alberta there are pulp mills at Hinton and near Grande Prairie. Several sawmills also operate in the foothills, around Lesser Slave Lake, and along the Athabasca, Pembina, and McLeod Rivers. Forests in northern Saskatchewan have not been extensively harvested, but stands could eventually be exploited in the area south of Lake Athabasca. Commercial operations are concentrated across the central part of the province, generally in the Churchill River basin, with a pulp mill near Prince Albert. In Manitoba, commercial pulp and paper operations are concentrated near The Pas and southeast of Lake Winnipeg.

In the Northwest Territories good timber-producing land is found on the plains of the upper Mackenzie, lower Slave, and Liard Rivers. Access, production, and transportation costs are high, however, and forest growth is slow, with trees taking as long as 200 years to mature. Currently, lumber mills operate near Watson Lake on the Liard River in the Yukon and at Fort Smith, Fort Resolution, Hay River, and Fort Simpson in the Northwest Territories. A pulp mill could eventually be developed on the Liard River near Watson Lake.

North of the Boreal Forest, closed forest gradually gives way to an open woodland and finally to tundra. A treeline divides the windswept, rocky, treeless Arctic tundra from the woodlands.

South of the Boreal Forest is a band of parkland, a mixture of woodland and grassland cover. The forests in this region are generally too small to support forestry operations, but in some places serve as shelter belts for the cultivation of rich grassland soils. They are also attracting some renewed interest as a potential source of fuel. Some forested land is scattered in relatively small pockets located in river valleys (especially on north-facing slopes) and in areas of relatively high elevation, such as the Cypress Hills.

Good agricultural soils in the Boreal Forest are found in the Peace River district and along the Athabasca, Pembina, and McLeod Rivers. Grain and livestock farming occur, with considerable room for expansion. Lengthy periods of daylight offer compensation for the short frost-free period. Land erosion and flooding are common problems in some areas.

Some farmland is also found in the floodplains of the Slave, Hay, Liard, and Mackenzie Rivers. Outdoor gardens have been grown as far north as Inuvik and Aklavik, and livestock, potato, and feed grain farming have been successful south and west of Great Slave Lake. However, climatic conditions, low soil fertility, limited local demand, high costs of production and transportation, and the fact that much of the arable land is forested make commercial agriculture undertakings very difficult north of 60° near the western boundary of the Study Region and north of 55° at the eastern boundary.

In the grasslands south of the parkland, the soils are a widely used resource. Uncultivated land supports large herds of beef cattle, but most of the best soils are now tilled. Brown, Dark Brown, and Black soils predominate. Solonetzic soils are widely scattered but salinity has inhibited their cultivation.

Although these grasslands make up the largest single expanse of agricultural land in Canada, there are several limitations for growing crops. Much of the area averages an 80-120 day frost-free period, barely adequate for some grain crops. Soil salinity is a serious and expanding problem in Saskatchewan and Alberta, and deficient soil moisture and drought are major restrictions in southern Alberta and southwestern Saskatchewan. A decline in soil productivity and a depletion of nitrogen have been noted in many areas. Soil losses due to improper tillage and losses of good agricultural lands to municipal developments are increasing concerns. Flooding is a serious agricultural problem in southern Manitoba. Thus, while there is some room for agricultural expansion, preservation of the land already under production is a serious concern. An illustration of the extent of lands taken out of agricultural production through urbanization is found in Table 7.

TABLE 7. URBANIZATION OF AGRICULTURAL LAND - EDMONTON AND CALGARY (1966-1973) (BENTLEY, 1980)

CANADA LAND INVENTORY SOIL CAPABILITY CLASSES (UNITS IN HECTARES)

	1	2	3	4	5	6
EDMONTON	4100	2300	600	100	100	800
CALGARY	100	2800	1600	700	1100	100

Fish and wildlife.

Fish are another important renewable resource in the region. Some species, such as walleye, yellow perch, and northern pike, are widespread, while lake trout and whitefish are primarily found in northern portions and a few lakes in the south. Goldeye and sturgeon are restricted to major river systems. A variety of trout species are located either naturally or artificially in the streams of the western mountains. Arctic grayling are restricted to Arctic Ocean and northern Hudson Bay drainage systems. A few trout species have been introduced in all three prairie provinces, and commercial rainbow trout farming has been promoted in sloughs in Manitoba.

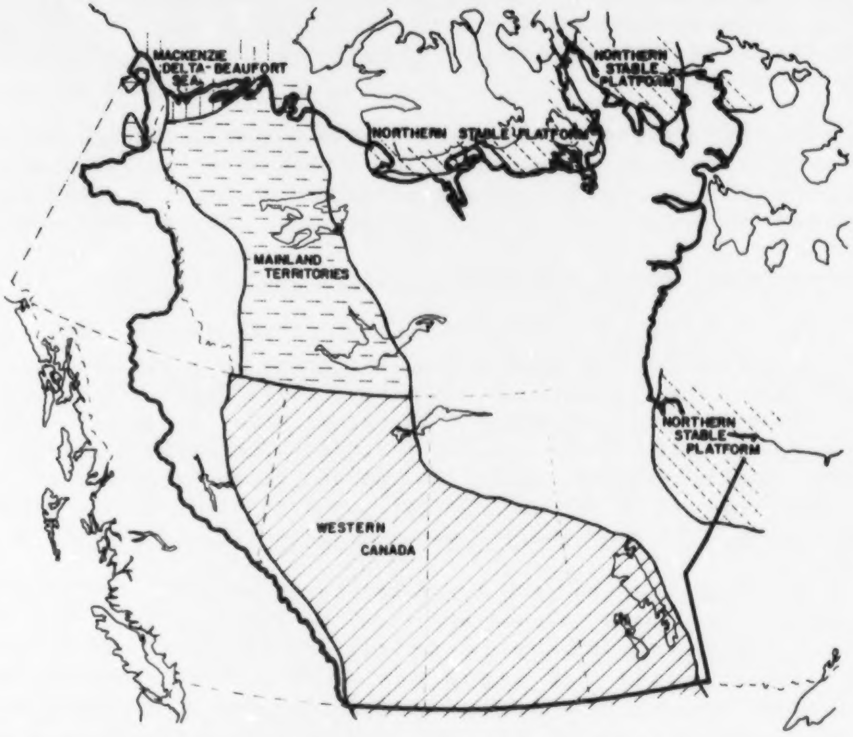
The wildlife of the Study Region has undergone remarkable changes over the past 200 years in the Plains region. Estimates of past bison populations in the northern plains of the United States and Canada range from five to ten million. Elk were also exceedingly numerous. Beaver built dams and flooded large areas along tributaries of the Red Deer, Battle, Carrot, and other streams, and vegetation in beaver ponds supported large populations of moose.

By 1900, bison were virtually eliminated through hunting, and the beaver were reduced to low levels by extensive trapping. More recently, agriculture, urban encroachment and industrial expansion, construction of large dams, mineral developments, forestry, and road construction have acted to reduce the capability of the land to produce and support wildlife.

Nevertheless, wildlife is still abundant in many areas. Deer, elk, moose, bighorn sheep, and mountain goats populate the mountains and foothills. Antelope, small fur-bearers, prairie dog, rabbits, and hare inhabit the grasslands, along with a great variety of waterfowl and other birds. The aspen parkland is a prime duck-producing habitat and upland areas support deer, elk, and grouse. The Boreal Forest contains bear, moose, elk, and deer, as well as many smaller mammals and a variety of bird life.

Hunting and trapping for subsistence purposes are important water-related uses in some areas of the Study Region. The Slave River and Peace-Athabasca Deltas are key links of four North American flyways for migratory birds. The Mackenzie Delta supports large populations of muskrat and beaver and serves as a major nesting, moulting, and staging area for several hundred thousand snow geese, swans, and ducks. Moose browse among the river and wetland willows and alders in winter, moving upland as warmer weather permits. Two major herds of caribou are the Porcupine herd of the northern and central Yukon, and the Kaminuriak found in the District of Keewatin and northern Manitoba. Wood Buffalo National Park supports the largest free-roaming herds of bison in North America and contains the nesting grounds of rare whooping crane. Otter and mink exist around many streams and deltas along with the beaver and muskrat. Dall sheep live on the high mountain slopes of the western boundary of the Mackenzie River basin. Other common animals include bear, arctic fox, wolf, lynx, martin, moose, and mountain goat.

Figure 12. POTENTIAL OIL AND GAS RESOURCE AREAS (PRCF, 1980).

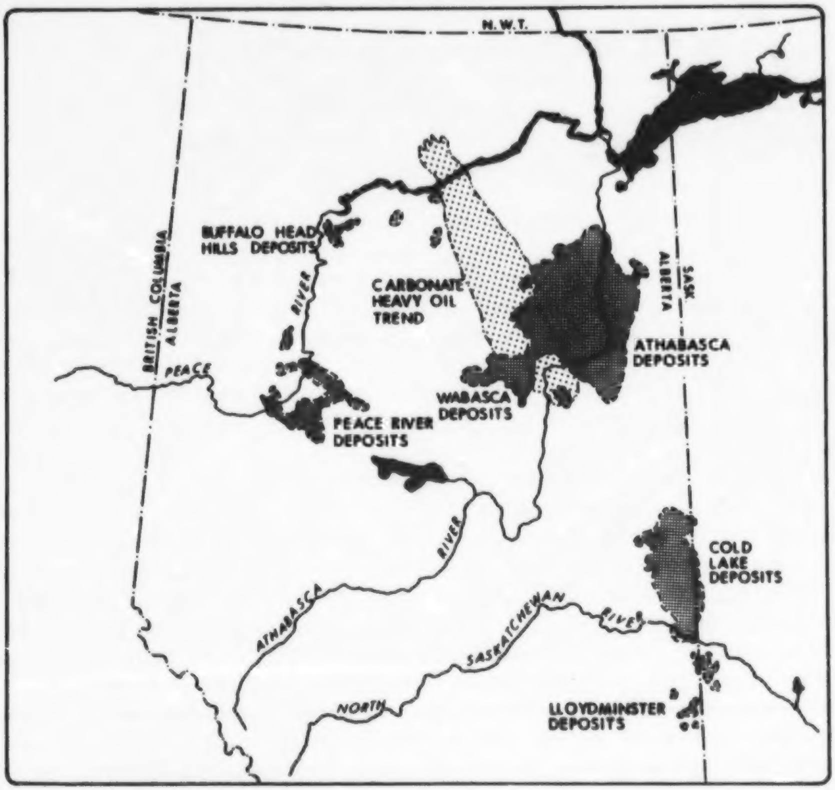

MACKENZIE DELTA-BEAUFORT SEA
NORTHERN STABLE PLATFORM
NORTHERN STABLE PLATFORM
MAINLAND TERRITORIES
NORTHERN STABLE PLATFORM
WESTERN CANADA

Non-renewable Resources

The petroleum resources of the Study Region presently rival its soils and vegetation in economic importance. Though exploited much more recently, they have risen dramatically in value in a world dependent on scarce and expensive sources of energy. Petroleum production began shortly after Canadian Pacific Railway drillers searching for water accidentally found natural gas near Medicine Hat in 1883. However, development was sporadic until 1947 when Imperial Oil made a major oil discovery near Leduc. Since then, oil and natural gas have been found to underlie most of Alberta and smaller areas in Manitoba, Saskatchewan, British Columbia, and the Territories. Virtually all of the Interior Plains region is now viewed as a potential oil and gas resource area (Figure 12). Producing oil and gas fields, however, are concentrated in Alberta, northeastern British Columbia, and along the western edge of Saskatchewan.

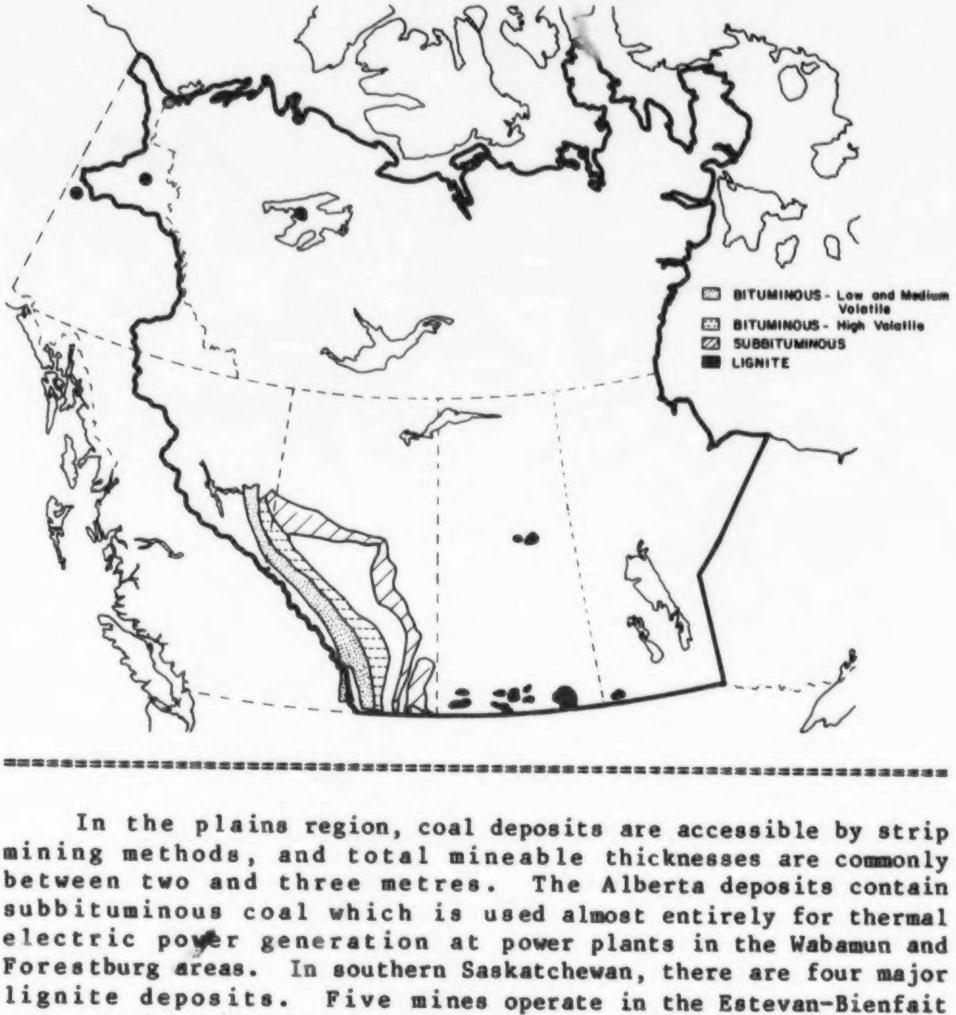
Less conventional sources of oil are increasing in importance. These include the Lloydminster, Cold Lake, Athabasca, Peace River, Buffalo Head Hills, and Wabasca heavy oil and oil sands deposits, and the massive oil reserve termed the "carbonate heavy oil trend" (Figure 13).

Figure 13. HEAVY OIL AND OIL SANDS DEPOSITS (PRCF, 1980).


N.W.T.
BUFFALO HEAD HILLS DEPOSITS
BRITISH COLUMBIA
ALBERTA
RIVER
CARBONATE HEAVY OIL TREND
SASK
ALBERTA
ATHABASCA DEPOSITS
PEACE
WABASCA DEPOSITS
PEACE RIVER DEPOSITS
RIVER
COLD LAKE DEPOSITS
ATHABASCA
SASKATCHEWAN
RIVER
NORTH
LLOYDMINSTER DEPOSITS

Coal also underlies a major part of the Study Region, as shown (by rank) in Figure 14. It was found in the Souris Valley as early as 1857, but it was not until the railways expanded in the west in the 1930s that coal production became significant. Peak annual production from the Drumheller region was reached in 1947; but with railway conversion to diesel power in the 1950s, the traditional markets for coal almost disappeared. Beginning in the late 1960s, coal began a return to prominence. Both in the manufacturing of coke for steel-making and as a source of heat in the production of electric power, it has assumed an important role in the western Canadian economy.

Figure 14. COAL DEPOSITS (Environment Canada, 1979b).


BITUMINOUS - Low and Medium Volatile
BITUMINOUS - High Volatile
SUBBITUMINOUS
LIGNITE

In the plains region, coal deposits are accessible by strip mining methods, and total mineable thicknesses are commonly between two and three metres. The Alberta deposits contain subbituminous coal which is used almost entirely for thermal electric power generation at power plants in the Wabamun and Forestburg areas. In southern Saskatchewan, there are four major lignite deposits. Five mines operate in the Estevan-Bienfait area, and a mine started production near Coronach in 1980. This coal powers electric generating plants near Estevan and Coronach, as well as stations near Saskatoon and in Manitoba.

Two mine complexes exist in the Alberta portion of the mountain region coal deposits. Bituminous coking coal is extracted from both underground and surface mines near Grande Cache on the Smoky River and from surface mines near Luscar, in the headwaters of the McLeod River. A small amount of cleaned thermal coal is also produced at Grande Cache for a nearby thermal electric power plant. A third surface mine, producing bituminous thermal coal, operates at Coal Valley near the source of the Pembina River, and another mine in the foothills region, along the Athabasca River, is scheduled to go into production in 1983. In northeastern British Columbia, detailed feasibility studies of production options for both thermal and coking coal are in progress. The deposits lie on the east slopes of the Rocky Mountains south of the Peace River. The region has undergone much exploration in the past several years and large mineable deposits have been identified.

Long-term predictions indicate that the demand for both thermal and metallurgical export coal will increase dramatically within the next 20 years, and demonstrated reserves are sufficient for the next 25 years. However, large amounts of coal will possibly not be mineable due to environmental constraints and conflicts with other land uses. Possible future water-related aspects of the coal industry include coal liquefaction and the transfer of coal by slurry pipeline.

Potash deposits in the Study Region extend in a belt from the Alberta border through central Saskatchewan down to southwestern Manitoba. These deposits are rich in potash (40-50 percent) and were first recognized in a core from an oil exploration well. Water seepage and flooding halted the first commercial attempts at production, but potash was mined successfully in 1962. The potash is usually extracted from layers two to three meters in thickness, at depths of 900-1100 metres. The ore is hoisted to the surface and the potassium salt refined from it. Eight conventional mines presently operate in Saskatchewan and recently one has been proposed for southwestern Manitoba. Solution mining, a technique exclusive to Saskatchewan, is used at a mine just west of Regina.

Potash reserves in the Study Region are enormous, enough for the entire world (at 1974 rates of consumption) for 3000 years. It is expected that price and demand will continue a long-term upward trend, doubling by 1990 (Saskatchewan Mineral Resources, 1976).

Metallic mineral exploitation is concentrated in the Canadian Shield portion of the Study Region. Except for precious metals, mining generally had to await the arrival of modern transportation. Manitoba had a thriving gold industry at the turn of the century, but gold is now produced only as a by-product of the mining of the other base metal ores. The first major property to be brought into production was near Flin Flon, where copper and zinc were discovered in relative abundance. These are also produced now in the Snow Lake and Lynn Lake areas. In 1957 "the largest underground development contract ever let in the history of the world" (Stewart, 1972) was made to develop nickel and copper deposits near Thompson, Manitoba.

Uranium is one of the most sought-after minerals in the Study Region. Two companies operate underground mines near Beaverlodge Lake, just north of Lake Athabasca in Saskatchewan, and a third extracts ore from deposits just west of Wollaston Lake. Production from one of the richest uranium deposits in the world began in 1980 near Cluff Lake, south of Lake Athabasca. Other occurrences, like those along the eastern arm of Great Slave Lake, west of Cree Lake, and in the District of Keewatin are being investigated intensively.

Exploration for lead-zinc deposits is conducted extensively in the Cordillera portion of the Study Region, though the only existing mines are near Pine Point, on the south shore of Great Slave Lake. Yellowknife is the centre of gold production, with two companies extracting and milling gold from nearby deposits. A third mine 300 kilometers north of Yellowknife may open soon. Just east of Great Bear Lake, three companies mine silver, copper, and bismuth from rich underground deposits. Tungsten ore and copper are extracted from underground deposits near the headwaters of the Flat River, a tributary of the South Nahanni River.

Among industrial minerals, salt leads in economic value and is produced in all three prairie provinces for both human consumption and as a raw material. Sodium sulphate is mined in significant quantities from shallow brine lakes in Saskatchewan and Alberta, primarily for use in the Kraft process of paper manufacture. Barite has been discovered along the Alaska highway in British Columbia; bentonite is found near Peace River; and commercial limestone exists near Fort McMurray and in the headlands of the Athabasca River. Gypsum occurrences are widespread, and manufacturers draw from the source most convenient to their operation. Commercial silica sand is found near Fort McMurray and along the Peace River. Asbestos was mined at Cassiar, B.C. on a tributary of the Peace River.

4. POPULATION

There has always been a close relationship between the inhabitants of the region studied and its waterways. The prehistoric peoples of the west and the north were probably as bound to the rivers and lakes as were the native populations (and later, the settlers from other continents) of historical record. Rivers were the highways, and they contributed vitally to the subsistence of all.

Today, there are strong remnants of those early relationships. Although the railways eventually offered a different basis for locating human settlements, we can still see that most of the largest cities have developed on major rivers. In the north the use of river transport continues, but in the southern areas the relationships between water and population have changed.

Municipalities, and the industries they attract, require water not just for domestic and a variety of industrial processing needs, but also for the many subsidiary aspects of urban development. Park, lawn, and golf course watering and fire-fighting are but a few examples of other municipal water uses.

TABLE 8. PROJECTED POPULATION GROWTH IN WESTERN AND NORTHERN CANADA
(STATISTICS CANADA)

	POPULATION (THOUSANDS)					
	1980[1]	1980[2]	1985	1990	1995	2000
MANITOBA	1 028	1 054	1 098	1 141	1 179	1 211
SASKATCHEWAN	969	972	1 026	1 066	1 100	1 128
ALBERTA	2 079	2 092	2 450	2 826	3 171	3 481
BRITISH COLUMBIA	2 637	2 613	2 860	3 154	3 433	3 686
YUKON	21	24	28	32	36	39
NORTHWEST TERRITORIES	43	48	56	64	71	77
CANADA	23 914	24 135	25 724	27 352	28 794	29 997

NOTE: PROJECTIONS WERE BASED ON THE 1976 POPULATION CENSUS AND ASSUME A NET INTERNATIONAL MIGRATION OF 75 000 PER YEAR AND A CONTINUED WESTWARD SHIFT IN ECONOMIC ACTIVITY.

1. ACTUAL
2. AS PROJECTED IN 1976

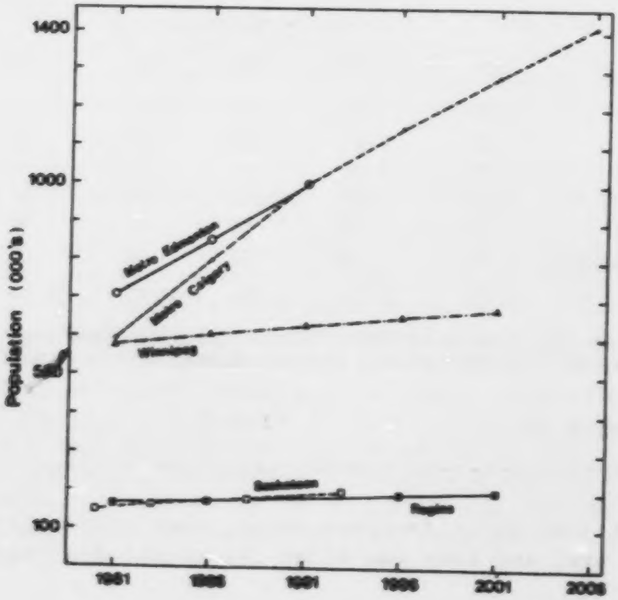
Cities not only require water, they profoundly affect the waters they use, and they can alter the normal drainage of water in their immediate areas. The latter results from the covering over of large areas by buildings and pavement. Water from precipitation is more readily drained to rivers than it would be if it were available for evaporation or transpiration from natural vegetation.

The major effects of cities, however, are on the quality of water. Municipal wastes, including sewage, can greatly affect downstream water users.

The population of the Study Region is therefore of interest in any analysis of water resources. The population of each of the provinces and territories is contained in Table 8. Also shown are projections of future growth. In each case, a positive growth is expected, and the largest increase is expected in Alberta.

The five largest cities: Winnipeg, Saskatoon, Regina, Calgary, and Edmonton, are of particular interest since they represent concentrations of water use. Population projections for those cities are contained in Figure 15. Calgary and Edmonton are each expected to surpass one million in the early 1990s.

Figure 15. POPULATION PROJECTIONS FOR REGINA, SASKATOON, CALGARY, WINNIPEG, AND EDMONTON.



Populations in the far north are not expected to change markedly in the near future except for fluctuations in transient populations associated with petroleum developments. Native populations are proportionately significant in the territories (over 50 percent in the NWT). Their impact on northern development, particularly with regard to land claim settlements, will undoubtedly increase.

Native communities in the provinces are less significant from a population viewpoint. Nevertheless, Indian interests in water are many. Historically, cultural and subsistence relationships have been important. More recently there has been a growing commercial involvement in fisheries, agriculture, and recreation.

There have been recent trends in the shifting of populations from farms to urban areas and in the consolidation of small farms. Many smaller communities are also giving way to the steadier growth of larger towns. These trends result in a greater concentration of water needs, which can be a problem in dry regions, where limited supplies are scattered.

TABLE 9. RURAL AND URBAN POPULATIONS - 1971 AND 1976

(STATISTICS CANADA, 1977, 1978A)

POPULATIONS IN THOUSANDS

	URBAN		RURAL		TOTAL	
	1971 (%)	1976 (%)	1971 (%)	1976 (%)	1971	1976
MANITOBA	686 (70)	714 (70)	301 (30)	307 (30)	988	1 022
SASKATCHEWAN	491 (53)	511 (56)	435 (47)	410 (44)	926	921
ALBERTA	1 196 (74)	1 379 (75)	431 (26)	459 (25)	1 628	1 838
BRITISH COLUMBIA[1]	1 654 (76)	1 897 (77)	530 (24)	570 (23)	2 185	2 467
YUKON	11 (61)	13 (61)	7 (39)	9 (39)	18	22
NORTHWEST TERRITORIES	16 (48)	21 (50)	18 (52)	21 (50)	35	43

1. INCLUDES THE POPULATION OF ALL OF BRITISH COLUMBIA, MUCH OF WHICH LIES OUTSIDE THE STUDY REGION.

The distributions of population between urban and rural categories is described in Table 9 for 1971 and 1976. For each jurisdiction, the percentage of population within urban communities has increased. The growth of many large urban centres in recent years has been impressive. In the five-year period between 1971 and 1976, most of the larger cities in the Study Region increased by between 5 and 7.5 percent. Another aspect of the concentrated nature of the population of western Canada is illustrated by the region's population densities, which range from less than one person per km^2 in the Yukon and Northwest Territories to between 150 and 1300 people per km^2 in the metropolitan areas of the provinces.

The rapid growth expected in western Canada, especially in areas of industrial expansion, will generate employment requirements which may exceed the capacity of the work force. For example, labor requirements for projected industrial growth are estimated to exceed the available work force by 733 000 by 1990, if no new people move into the region (DREE, 1980a). Thus the development expected in western Canada may be limited to a degree by a people-shortage.

5. ECONOMIC DEVELOPMENT

While well endowed with a variety of natural resources, the region's early settlement and development were founded primarily upon prairie grain production. Although other resources have increased in significance in the economy, agriculture remains a major industry throughout the prairie provinces.

The National Policy of 1867 encouraged the development and delivery of natural resources to the east through a system of trade, tariff, and transportation arrangements. These factors have encouraged the production and shipping of primary products, but have tended to restrict and limit the effectiveness of agriculture in stimulating the large-scale development of secondary industries in western Canada. Wheat exports became a major stimulus and today the region continues to be an important supplier of wheat and other grains, livestock, and forage crops.

Agriculture is most diversified in the province of Alberta. Since the 1930s, wheat production in central Alberta has declined in prominence and has been replaced by forage crops. Other diversification has been related to livestock operations in the southwestern part of the province, dairying in central Alberta in response to the needs of growing urban centres, rapeseed in the Peace River and Vulcan areas, and vegetables in the irrigation areas of the south. Manitoba is similar to Alberta in terms of its mixed farming, although livestock is much less important and irrigation is much less extensive. Vegetables, potatoes, and sugar beets are grown along the Red River valley, while corn for silage, and other special crops, are produced throughout the southern portion of the province. Saskatchewan is the least agriculturally diversified of the three provinces. Wheat has always dominated its agricultural economy, although rapeseed and feed grain crops are grown in the eastern part of the province.

Other primary sectors have increasingly served to stimulate the western economy. Since the 1940s the development of oil, natural gas, oil sands, coal, potash, and other metallic and non-metallic minerals has made substantial contributions to growth in western Canada. However, a concentration on extraction and primary processing of only a limited range of resources has left the region vulnerable to the vagaries of weather, and to volatile fluctuations of international commodity markets.

TABLE 10. PEOPLE EMPLOYED BY MAJOR INDUSTRY, 1961 & 1971

(CENSUS OF CANADA, 1961 AND 1971)

	PRAIRIES				NWT & YUKON			
	1961	%	1971	%	1961	%	1971	%
AGRICULTURE	282 111	24.4	234 450	15.9	57	.4	20	.1
FISHING/TRAPPING	3 259	.3	840	.1	1 687	12.3	395	2.1
FORESTRY	5 244	.5	3 690	.3	83	.6	170	.9
MINES	26 977	2.3	41 765	2.8	2 002	14.6	2 340	12.2
MANUFACTURING	104 107	8.9	139 265	9.4	241	1.8	490	2.6
CONSTRUCTION	75 598	6.5	92 680	6.3	727	5.3	1 000	5.2
TRANSPORTATION	117 486	10.1	122 295	8.3	1 871	13.7	2 280	11.9
TRADE	183 045	15.8	221 110	15.0	892	6.5	1 790	9.4
FINANCE	34 037	2.9	51 670	3.5	94	.7	295	1.5
COMMUNITY BUSINESS	216 228	18.7	344 680	23.4	2 403	17.5	4 080	21.4
PUBLIC ADMINISTRATION	83 403	7.2	114 575	7.8	3 217	23.5	3 510	18.4
UNSPECIFIED	26 241	2.3	106 260	7.2	420	3.1	2 730	14.3
TOTAL	1 157 742		1 473 270		13 694		19 105	

	1961				1971			
	PRAIRIES	%	NWT & YUKON	%	PRAIRIES	%	NWT & YUKON	%
PRIMARY	317 591	28	3 829	28	280 745	19	2 925	15
SECONDARY	297 191	25	2 839	21	354 240	24	3 770	20
TERTIARY	542 960	47	7 026	51	838 295	57	12 405	65

Several authors (Barr, 1972 and Hanson, 1966) have suggested that the discovery of oil at Leduc in 1947 was the beginning of the reorganization of the prairie economy. Table 10 provides a breakdown of employment, by industry, in 1961 and 1971 and provides an indication of the large shifts that occurred out of agriculture and towards the mining and tertiary sectors.

In 1961, agriculture accounted for approximately 24 percent of the prairie labour force. By 1971, only 16 percent of the work force earned its livelihood in this sector. The mining sector, however, increased its labour force by 55 percent, attributable primarily to oil and gas developments. Estimated employment for 1980 in the prairie provinces, by industry, is presented in Table 11.

TABLE 11. ESTIMATED EMPLOYMENT IN THE PRAIRIE PROVINCES
BY INDUSTRY FOR 1980 (000 s)
(STATISTICS CANADA, 71-001)

	MANITOBA	SASKATCHEWAN	ALBERTA	TOTAL	PERCENTAGE
AGRICULTURE	44	92	82	218	11.3
OTHER PRIMARY INDUSTRIES	7	11	66	84	4.4
MANUFACTURING	64	23	108	195	10.1
CONSTRUCTION	23	25	99	147	7.6
TRANSPORTATION	50	35	87	172	8.9
TRADE	80	72	192	344	17.9
FINANCE	24	19	55	98	5.1
SERVICE	133	110	289	532	27.7
PUBLIC ADMIN.	34	31	68	133	6.9
TOTAL	459	418	1046	1923	
PRIMARY	51 (11%)	103 (24.5%)	148 (14%)		
SECONDARY	137 (30%)	83 (20%)	294 (28%)		
TERTIARY	271 (59%)	232 (55.5%)	604 (58%)		

The period 1961 through 1980 has been one of transition, away from an economy dominated by agricultural production to a more diversified economy encompassing development of both renewable and non-renewable resources, increased manufacturing of these resources, and a strong growth in the tertiary sectors of the economy. Yet, despite these recent decades of growth and change, the development of a more diverse and strengthened manufacturing base continues to elude the region.

The Yukon and Northwest Territories have both experienced a decline in the labour force engaged in primary industries, but the mining sector has experienced a moderate increase. Although no current figures are available on employment distributions in the north, it is likely that the mining sector employment has increased significantly in concert with recently expanded developments in the region. Minerals such as lead, nickel, zinc, and copper provide a basis for long-term economic development.

In recent years the principal resources stimulating economic growth in the north have been oil and gas, and to some extent, forest products. During the 1970s, exploration and development of Arctic oil and gas overshadowed other mining activities.

For the region as a whole, the increase in the labour force employed in secondary and tertiary industries can be attributed, in large part, to the boom associated with oil, gas, coal, potash, uranium, hydro-electric developments, and other mineral products development, and in the manufacture of petrochemicals.

Manufacturing comprises an important aspect in the expansion of the region's economic base. In 1980, the five leading manufacturing industries (in terms of value of shipments) were: food and beverages, petroleum and coal, chemical products, metal fabrication, and the machinery industry. These five industries accounted for over 60 percent of the total value of manufactured shipments. The primary metals sector; the non-metallic industry; and the wood, paper, and printing sectors contributed another 20 percent to the total of manufactured shipments.

In general, the employment effects of various natural resource developments have been felt more in the financial and services sectors rather than at the manufacturing level, where they are most desired, at least from the viewpoint of governments. As implied earlier, the inability to expand secondary industries involves a large number of complex factors that include tariffs, transportation rates and policies, size of markets, foreign ownership, and the lack of qualified labour, among others.

The dependence of western Canada on primary industry, particularly mineral products, has been recognized by all provincial and territorial governments. Governments are attempting to diversify their economies by reducing exports of primary products and by encouraging the further processing of those products where they have a locational advantage. This last point was strongly emphasized by the Hall Commission (1977).

The abundance of renewable and non-renewable resources has provided a basis for continued optimism towards future growth in western Canada. The region is perhaps unique in comparison with other producing regions of the world, for within the western provinces and territories are large reserves of coal, natural gas, uranium, oil, oil sands, heavy oil, and untapped hydro resources. These resources ensure that the region will continue to be a significant energy producer long after conventional oil reserves have been economically depleted. The extraction and processing of these resources in the primary sector will have a catalytic effect in increasing the size and augmenting the strength of other sectors in the economy.

TABLE 12. MAJOR PROJECTS IN THE WEST BY SECTOR AND JURISDICTION

(DINA, 1981)

(MILLIONS OF DOLLARS)[A]

	MAN	SASK	ALTA	BC	YK.T	NWT	TOTAL
OIL & GAS EXPL. & DVMT.	—	—	500	—	—	60,700	61,200
REFINING & GAS PLANTS	—	—	625	250	—	2,500	3,375
HEAVY OIL DVMT. & UPGRADING	—	2,750	42,405	—	—	—	45,155
PIPELINES	3,020	1,205	2,835	4,145	6,140	8,840	26,185
HYDRO-ELECTRICITY	5,865	1,635	3,815	22,175	100	—	33,590
THERMAL-ELECTRICITY	—	1,525	16,435	5,070	—	—	23,030
COAL MINING	—	—	3,230	2,870	—	—	6,100
URANIUM MINING	—	1,365	—	—	—	—	1,365
ELEC. TRANSMISSION	4,720	210	200	2,465	—	—	7,595
LNG	—	—	—	2,900	—	2,000	4,900
COAL GASIF./LIQUE	—	—	2,200	5,000	—	—	7,200
TRANSPORTATION TO/FROM ENERGY FIELDS	—	—	100	650	—	150	900
PETROCHEM.	—	300	8,160	2,515	—	—	10,975
FOREST PRODUCTS	—	—	1,200	3,320	—	—	4,520
POTASH	500	2,600	—	—	—	—	3,100
METALS MINING	—	—	—	2,755	1,240	265	4,260
TRANSPORTATION[B]	—	—	855	1,235	180	—	2,270
ALUMINUM	500	—	—	2,000[C]	—	—	2,500
TOTALS	14,605	11,590	82,560	57,350	7,660	74,455	248,220
PERCENTAGE	5.9	4.7	33.2	23.1	3.1	20.0	100.

(A) MULTI-JURISDICTION PROJECTS ARE DISTRIBUTED AMONG JURISDICTIONS ON THE BASIS OF ESTIMATED PORTIONS.
(B) NOT TO/FROM ENERGY FIELDS
(C) MUCH OF THE B.C. ALUMINUM PROJECT COULD BE FOR HYDRO-ELECTRICITY

A recent summary by the Consultative Task Force on Industrial and Regional Benefits from Major Canadian Projects (MPTF, 1981) describes the projects for each jurisdiction in terms of billions of dollars to the year 2000. Nationally, and within the region, the energy sectors predominate in future economic development scenarios. On a national basis, 88 percent of mega-project dollars are to be committed to energy related projects. Within the western region, 89 percent of mega-project expenditures are to be in the energy sectors. The percentages increase over time: from 33 percent in the early 1980s, to over 90 percent in the 1990s and beyond.

The Frontiers Within (DINA, 1981) provides further details of these large projects in the western and northern regions. Major project investment expenditures, by industrial sector, are shown in Table 12. Almost 250 billion dollars has been contemplated for future investments throughout the region. Within the energy component, three sectors account for approximately two-thirds of the major investments in the west and north: oil and gas exploration, development, and processing, including heavy oils and liquefied natural gas (44 percent); hydro electricity (13 percent); and thermal electric developments (9 percent).

While the Study Region includes only the northeast corner of British Columbia and the eastern portions of the Yukon, a significant portion of future provincial and territorial investments (approximately 30 percent and 40 percent, respectively) is planned for these areas.

The timing of many of these developments is noteworthy. Sixty percent of Alberta's heavy oil developments are scheduled to begin after 1984. Approximately 80 percent of the hydro projects are not scheduled to commence until after 1984, and the majority of these will not be brought on-stream until the 1990s.

Hydro-electric developments will play a major energy role in both Manitoba and British Columbia. In Alberta, heavy oil and thermal electricity are the most significant. In Saskatchewan, the energy sector is more evenly distributed among heavy oil, hydro, thermal, and coal. In the north, oil and gas exploration and development are dominant. The Northwest Territories is almost wholly dependent upon oil and gas exploration and development, processing, and transportation. The Yukon is 80 percent dependent upon transportation (pipelines).

Continued growth in the region is inextricably intertwined with the prosperity of all Canadians. The disparities that exist between western and central Canada are not so much in terms of poverty, but in terms of lagged economic development. With much of its future contingent upon resource developments, the need is great for the region to develop mutually agreeable development policies that are supported at all levels and that provide an impetus for industrial expansions in the west and north. The need is also great to examine future water supplies and demands created throughout the region by the combined pressures of population, municipal, agricultural, and industrial developments.

6. CULTURAL DEVELOPMENT

In addition to population growth and economic development, there exists a variety of human social and cultural activities which affect and are affected by water resources. These include human use of the natural environment for purposes of recreation, and the perceived need to act in some responsible way as stewards of the natural environment. Each of these has some measure of economic implication, and yet the main issues with respect to the use and protection of water resources for these purposes are not usually considered in terms that are measurable.

During the 1960s, per capita disposable income, leisure time, and accessibility to transportation facilities increased dramatically in the Study Region. This resulted in very significant increases in the demand for water-based recreational activities. Fisheries and Environment Canada has stated that 75 percent of all outdoor recreation is water-oriented. Thus, severe pressures have been exerted on water-based recreational areas, resulting in direct conflict with other more established water uses, such as power developments.

These pressures have been particularly strong in the national parks, where some of the country's highest quality water resources are present. Attendance at national parks in Canada increased by six percent per annum from 1966 to 1973, and approximately 17 million people visited the parks during the 1973/74 fiscal year. By 1978/79, the annual attendance had increased to about 19.4 million visits.

The establishment of national and provincial parks is, however, not just for the provision of recreational facilities. Parks and preserves also reflect human stewardship concerns. Indeed, the management of national parks in Canada has always been confronted by the dilemma of the potential conflict between recreational use and preservation.

The National Parks Act of 1930 states that: "The parks are hereby dedicated to the people of Canada for their benefit, education, and enjoyment, subject to the provisions of the Act and the regulations, and such parks shall be maintained and made use of so as to leave them unimpaired for the enjoyment of future generations."

At one extreme, highly organized recreational facilities, including housing and highly sophisticated recreational development facilities can be found in Banff, Jasper, and Riding Mountain National Parks. On the other hand, efforts to totally restrict park use that is detrimental to the natural state of the environment exist in portions of Nahanni and Wood Buffalo National Parks.

Parks Canada has initiated a program in partnership with the provinces and territories to identify "heritage rivers". If implemented, this program would identify rivers of historical importance and rivers that are presently unaffected by development. The degree to which specific rivers would be protected in this program will depend upon agreements reached between the jurisdictions.

Each of the provinces in the Study Region has a provincial parks program. There also exist other protected lands variously termed refuges, reserves, wildlife areas, and sanctuaries. Each serves purposes related to conservation of lands and waters, either for recreation or stewardship. The locations of parks and other protected lands are described in Chapter VIII.7 (Figure 97).

7. WATER MANAGEMENT

Each of the provinces in the Study Region is responsible for the management of the waters within its boundaries as a result of the transfer of ownership of natural resources from the federal government in 1929 (Manitoba and Alberta) and 1930 (Saskatchewan and British Columbia). Municipalities come under provincial jurisdiction and are responsible for many aspects of local water management such as water supply and waste treatment. Federal technical and financial assistance is made available to municipalities through agreements with the provinces. The federal government has certain direct responsibilities related to water which are described below, followed by detailed information regarding the water management structures of each of the provinces.

The legal instruments of water management, and issues related to them, are described in the next section. Included is a more detailed discussion of provincial and federal legislation referred to in the following.

Federal

The British North America Act (BNA) of 1867 provides the federal government with the power to legislate over a number of specific matters that affect water, and has provided it with a general responsibility for planning and managing water resources where there is a significant national interest. This includes, but is not limited to, the management of boundary and international waters; waters in Indian reserves, national parks, and the Territories; and interprovincial waters. The federal government also maintains jurisdiction over matters relating to fisheries and navigation.

The federal government and the governments of each of the provinces have determined several areas where there is a basis for joint management. These include agricultural uses, inland fisheries, joint planning regarding multi-jurisdictional water quantity and quality concerns, and the planning and implementation of water activities that are of national interest, within individual provinces. The federal government claims a general mandate for "...conducting research, collecting data and maintaining inventories relating to surface and subsurface water, pollutants and contaminants, fisheries and aquatic ecosystems, atmospheric water, snow and ice" (Fisheries and Environment Canada, 1978b).

There has been a greater degree of federal involvement in water management in the past. In recent years, as provinces have more fully assumed their roles in water management affairs, and the federal government has increasingly devolved its activities in favour of the provinces, there has been a trend toward restriction of federal activities to those areas which are strictly within its jurisdiction.

The federal government has enacted several pieces of legislation pertaining to the management of water. The most fundamental of these is the Government Organization Act which, as of December 1980, contained sections defining the responsibilities of the Departments of Environment, Fisheries and Oceans, Agriculture, Regional Economic Expansion, and Indian Affairs and Northern Development, each of which bears specific federal water responsibilities.

The Boundary Waters Treaty Act describes the federal government's responsibilities to the Boundary Waters Treaty with the United States. The International River Improvements Act enables the federal government to undertake certain measures which protect Canada's interests in dealing with waters shared with the United States.

The Prairie Farm Rehabilitation Act, passed by Parliament in 1935, enables the federal government to assist in reclamation of agricultural lands seriously affected by drought and soil drifting in Manitoba, Saskatchewan, and Alberta. Subsequent amendments to the Act widened the scope of Prairie Farm Rehabilitation Administration (PFRA), extended indefinitely the life of the original legislation, and relaxed PFRA boundaries to include all agricultural areas of the four western provinces.

The Canada Water Act was established as a means for joint federal-provincial actions pertaining to water issues within a specific province or provinces that have both provincial and federal implications. The Act also provides for unilateral federal action, but that portion of the Act has never been employed. A number of regional planning studies, and in some cases implementation of measures found necessary, have occurred in the Study Region, including:

- the Peace-Athabasca delta;
- the Qu'Appelle River basin;

- the Souris River basin;
- the Churchill River;
- the Lower Saskatchewan basin;
- Lake Winnipeg, and the Churchill and Nelson Rivers;
- the Mackenzie River basin;
- the Red River Valley.

Also under the Canada Water Act are Flood Damage Reduction programs with the Northwest Territories, Manitoba, and Saskatchewan; and a cooperative program of water quality monitoring related to the Garrison Diversion in the United States.

The federal Fisheries Act provides the basis for federal action in water quality protection. Regulations or guidelines to limit effluents damaging to fish are defined for a number of industries and activities.

Other federal acts are the Arctic Waters Pollution Act, the Northern Inland Waters Act, the Navigable Waters Protection Act, and the Canada Shipping Act. Each of these enables the federal government to play a role in the evaluation of activities that would threaten water quantity and/or quality requirements. The Migratory Birds Convention Act also contains provisions that enable federal regulation of activities that threaten the quality of waters necessary for migratory birds. The Environmental Contaminants Act enables federal activities regarding specific pollutants of significant national interest.

The principal arm of Environment Canada dealing with water is the Inland Waters Directorate. In the Study Region, its Regina-based headquarters has district offices in Winnipeg, Calgary, and Yellowknife. The Water Resources Branch operates streamflow and sediment networks both for federal purposes and (with cost recovery) for the provinces and territories. Some stations are cost-shared because there are both federal and provincial/territorial interests. The Water Quality Branch operates water quality station networks and develops policies and objectives for water quality. The Water Planning and Management Branch develops policies and projects related to federal and interjurisdictional water programs.

The agency of Environment Canada responsible for developing and enforcing regulations is the Environmental Protection Service. Its major programs include water pollution control, environmental impact control, federal facilities clean-up, environmental emergencies, and waste management.

Also within Environment Canada are Parks Canada, responsible for development and administration of national parks and related activities, and the Canadian Wildlife Service, which has responsibilities related to the Migratory Birds Convention Act. The latter includes management of waterfowl and, in cooperation with the provinces, waterfowl habitat. There are also other agencies within this and other federal departments whose activities relate to water, but which are not included in this summary.

The Department of Regional Economic Expansion (DREE) is responsible for the programs of the Prairie Farm Rehabilitation Administration (PFRA) and the Agricultural and Rural Development Administration (ARDA). In the prairie provinces, the PFRA is the operating agency for both programs. For over 45 years, PFRA projects have assisted in the rehabilitation of agricultural lands through conservation and water supply enhancement means, in cooperation with the provinces. Both on-farm and community projects are widespread throughout the southern portions of the Study Region.

The federal Fisheries and Oceans department manages and develops Canada's fisheries and conducts inland fisheries research, mainly at the Freshwater Institute, Winnipeg. Much of its work is related to the federal Fisheries Act, mentioned earlier.

The Northwest and Yukon Territories are federal lands. The federal Department of Indian Affairs and Northern Development is primarily responsible for water resource matters in the two territories, including the development and management of waters in the north; the construction and operation of facilities for water supply, waste disposal, and pollution control; and the administration of the Northern Inland Waters Act. It also administers the Arctic Waters Pollution Act and Regulations and the Territorial Land Use Regulation. The NWT Water Board and the Yukon Territory Water Board, established under the Northern Inland Waters Act, supervise water use and water quality protection in their respective territories.

Environment Canada maintains some interest in waters in the north through the Migratory Birds Convention Act and the Ocean Dumping Control Act. Through its Inland Waters Directorate, it also constructs, operates, and maintains a network of hydrometric and water quality stations in the territories, partly in pursuit of the interests of the department, and partly on behalf of the Department of Indian Affairs and Northern Development.

The Northern Canada Power Commission constructs and operates public utility plants in the north under the mandate of the Northern Canada Power Commission Act.

Manitoba

In Manitoba, the Department of Natural Resources includes the branches responsible for fisheries, forestry, lands, parks, water, and wildlife. The Water Resources Branch is responsible for the administration of legislation relating to the planning, development, allocation, and management of water resources available to Manitoba. The legislation relating to these responsibilities is contained in the Water Resources Administration Act, the Water Rights Act, the Water Power Act, the Rivers and Streams Act, the Ground Water and Water Well Act, the Water Supply Districts Act, the Conservation Districts Act, and the Dyking Commissioner Act.

The Water Resources Branch is organized into the Water Management Service, which is responsible for planning, conservation districts, and drainage and flood control works; the Water Investigation Service, which is responsible for hydrologic studies, groundwater, and flood forecasting; and the Water Licencing Service, which is responsible for the issuing and monitoring of licences under the Water Rights and Water Power Acts. The water programs, including engineering service to municipalities, are delivered through a regional water manager service.

Responsibility for water quality and other environmental aspects is with the Department of Consumer and Corporate Affairs and Environment, in the Environmental Management Division. One arm deals with the inspection, control, and environmental assessment, while another deals with laboratory services, standards, and water quality studies.

The Department of Agriculture, through the Manitoba Water Services Board and the Agri-Water Program, provides grants and technical assistance to communities and individuals for the installation of water supplies, including sewage systems. The Department is responsible for the provision of technical and financial assistance for the development of on-farm irrigation systems.

Saskatchewan

The Department of Environment is responsible for most matters concerning the regulation of water resources in

Saskatchewan. It administers environmental laws that give it the authority to monitor, regulate, and prevent pollution, and assess the impact of proposed new developments.

The Environmental Protection Service contains two operational branches related to water. The Water Pollution Control Branch monitors water quality, investigates water quality problems, and sets water quality objectives. The Land Protection Branch develops and administers management programs for urban areas subject to severe flooding, and shorelands management policies and programs.

The Water Management Service contains three water-related branches. The Water Rights Branch is a water-use regulatory agency and the Hydrology Branch conducts hydrologic investigations, carries out reservoir and river system operation planning, and is responsible for investigations conducted on approved intergovernmental studies. The Qu'Appelle Implementation Branch deals with the implementation of projects under the federal-provincial Qu'Appelle Implementation Agreement.

The Policy, Planning, and Research Branch develops and coordinates environmental planning and research programs and develops policy guidelines for resource development and management. Along with the Hydrology Branch it provides input to interjurisdictional studies such as the Mackenzie River basin study.

The Environmental Assessment Secretariat screens development proposals to determine need for environmental impact studies and coordinates government participation in the impact assessment and review process.

Legislation administered by Saskatchewan Environment includes the Department of the Environment Act, the Water Rights Act, the Water Resources Management Act, the Drainage Control Act, the Environmental Assessment Act, the Water Power Act, and the Ground Water Conservation Act. The Saskatchewan Department of Health administers the Public Health Act, and Saskatchewan Agriculture administers the Conservation and Development Act and the Watershed Association Act. Provincial licenses are required for allocation of all surface and ground waters.

The Saskatchewan Department of Agriculture is responsible for drainage and irrigation projects; farm, hamlet, and village water and sewage programs; and farmstead pollution control. The

Department of Tourism and Renewable Resources assists in the development of waters associated with recreation and administers fisheries and wildlife. The Saskatchewan Power Corporation constructs and operates water power facilities, and the Department of Northern Saskatchewan oversees resource developments in the north. The departments of Urban Affairs, Rural Affairs, and Health, and the Saskatchewan Water Supply Board all have responsibilities related to water.

Alberta

The Department of the Environment is responsible for water resources management in Alberta. The sector of the Department primarily involved in water management is the Water Resources Management Service which administers a program addressing multi-purpose water needs and water-related problems. This is achieved through the activities of six Divisions responsible for: surface water development and control, regulatory and regional advisory services, operation and maintenance of water resources systems, data collection and inventory, water resources planning and coordination, groundwater development, and water rights administration.

The legislative acts related to water quantity management in Alberta include: the Water Resources Act, the Drainage Districts Act, the Groundwater Control Act, and the Irrigation Districts Act.

Water quality in Alberta is managed by the Environmental Protection Service which administers a program of pollution control to attain a safe and publicly acceptable level of water quality in the province. This is achieved through a program of standards development, letting permits, licensing, and control through monitoring, assessment, and enforcement activites.

The legislative acts related to water quality management in Alberta include: the Department of Environment Act, the Clean Water Act, the Agricultural Chemicals Act, the Litter Act, the Hazardous Chemicals Act, and the Waste Management Act.

The province's water resources are managed on a river basin system, with planning organized around the six major river basins in Alberta. Alberta grants the rights to water usage through the issuance of water use licenses. The user, under the terms of the license, must accept terms and conditions designed to protect the source of supply and the rights of others. The issuance of licenses is based on a priority system which ranks water uses in order of priority as follows: domestic, municipal, agricultural, industrial, and other. "Multi-purpose use of water impoundments and conveyance facilities is an underlying principle" (Alberta Environment, 1980d) and an indication of the approach being adopted by the province in attempting to meet the needs of its diverse water uses.

The Alberta Department of Energy and Natural Resources is responsible for fish and wildlife and the Alberta Forest Service, with associated implications for water management. The Department of Recreation and Parks is responsible for provincial parks and other aspects of water based recreation.

The Irrigation Division of Alberta Agriculture has responsibilities for irrigation services and planning. An Irrigation Council, with its Irrigation Secretariat, administers the Irrigation Act and approves the expenditure of funds received by irrigation districts as a result of any cost-sharing programs with the Government of Alberta. Private irrigation is licensed through Alberta Environment which is also responsible for the construction and operation of major irrigation works.

British Columbia

In British Columbia, the Ministry of Environment is responsible for allocating and managing the province's water resources, empowered under the Water Act, the Water Utilities Act, and the Energy Act. Authority and responsibility for resource management is regionalized in British Columbia, and only the Omineca-Peace region is in the Study Region.

The Water Management Branch of the Environmental Management Division issues water licenses, monitors and approves designs and construction programs for major power projects, operates a dam inspection program, and regulates privately owned water utility companies. Liaison is maintained with the British Columbia Hydro and Power Authority (B.C. Hydro) with respect to ongoing studies of potential major power developments. Branches within the Assessment and Planning Division and Environmental Services operate programs directed at flood damage prevention, water supply utilization, environmental preservation, and protection of community watersheds.

The recent British Columbia Utilities Commision (BCUC) Act requires that all energy generation projects must now obtain an Energy Project Certificate. The first project that will receive consideration by the BCUC is the B.C. Hydro Site C project on the Peace River.

Northwest Territories and Yukon

In addition to the federal roles in the north, each of the territorial governments exercises some responsibility for natural resources. In the Northwest Territories, the Environmental Services Division of the Department of Renewable Resources administers environmental protection, pesticides, public health, and petroleum products storage ordinances; responds to oil spills; and participates in regional scientific and development planning (GNWT, 1981b).

The Yukon Territorial Government undertakes similar efforts, and is interested in expanding its role in water resource management as part of its aspirations to achieve provincial status.

In addition to their respective water management agencies, each province has a number of institutions which serve as advisory or provincial research councils. The Environment Council of Alberta, the Saskatchewan Environmental Advisory Council, the Manitoba Environmental Council, the Manitoba Water Commission, the Manitoba Clean Environment Commission, the Alberta Research Council, the Saskatchewan Research Council, and the B.C. Research Council each has a role that, to varying degrees, is of some assistance to provincial water departments.

In 1948, Alberta, Saskatchewan, Manitoba, and Canada established the Prairie Provinces Water Board (PPWB) to recommend the best use of eastward-flowing interprovincial waters and to recommend allocations between the provinces. In 1969, the Board was reconstituted by the Master Agreement on Apportionment which, in general terms, entitles the provinces of Alberta and Saskatchewan to use and consume up to one-half of the natural flow of eastward-flowing streams originating in or flowing through these provinces. Eleven locations have been designated for the establishment of monitoring stations. Water quality objectives have also been set for these stations (PPWB, 1973), and a committee is presently in the process of setting water quality requirements for each station. The Board has adopted Interim Water Quality Requirements for the Beaver River at the Alberta-Saskatchewan boundary.

In 1977, the PPWB commenced Part One of a Water Demand Study of historical and present water demands in the three provinces. The PPWB has been cooperative in supplying some of the information generated by their study to this report.

Increasingly, native peoples are becoming directly involved in the resolution of water resource issues that affect them or their lands. This ranges from large-scale land claims negotiations involving such organizations as the Committee on Original People's Entitlement (COPE), to negotiations regarding specific works (e.g., works on the Oldman River on the Peigan Reserve in Alberta), to local basin planning (an aspiration of the Qu'Appelle Valley Indian Development Authority).

8. WESTERN CANADIAN WATER RESOURCES LAW

A comprehensive survey of western Canadian water law has been prepared by Per Gisvolds (1959). That work is still useful, though parts are badly outdated, and immense work would be required to prepare a full treatise on western Canadian water law. What follows is, instead, a general overview of legal principles and issues.

Riparian Rights

The English Law of Water Rights was introduced in Western Canada as part of the general body of English Law received in the Northwest Territory of Canada as of July 15th, 1870. The basic doctrine was that of riparian rights, which had developed through a series of nineteenth century English and eastern United States cases. Features of the riparian doctrine follow from the premise that water should be regarded as public property that cannot be exclusively owned like other real property interests. Consequently, the law, through judicial decisions, defined rights to the use and flow of water, rights that are vested exclusively in riparian property owners. Riparian owners are those whose property abuts bodies of water.

Riparian rights relate both to flow (quantity) and use (quality), and include the following:

1. An unlimited right to use water for "domestic purposes". Basically the water needs of a small nineteenth century agriculture holding were used as a standard for defining domestic use.

2. The right to receive water substantially undiminished in flow and substantially undiminished in quality.

3. The right to use water for "secondary" or "extraordinary" purposes, so long as the use is "reasonable" and for a purpose connected with the riparian property. Reasonableness of water use came to be regarded as a question of fact based, among other things, on the character of the use, size of the stream, climate and customs of the region, and the user's economic "necessities".

Riparian principles, however, became strained by the rapid industrialization of the late nineteenth century. One line of English cases suggests that the riparian right to receive water is to be interpreted relatively strictly. Another line of cases, however, developed the more flexible concept of "reasonable use" in order to authorize industrial and natural resource development that had a marked effect on downstream uses. The reasonable use doctrine clearly prevailed both in England, the United States, and Canada. As a result, legally justified developments gradually resulted in an overall reduction in water quantity and quality.

When riparian law was applied in the dry regions of western Canada, the problem that had already become apparent with the riparian doctrine was significantly magnified. In water-short areas, "reasonable use" by numerous riparian owners quickly limited the quantity and quality of water available to any particular user. A point was quickly reached where dryland farming and ranching activities that were necessarily water-intensive could not be guaranteed water supplies under the riparian system.

Canadian courts, bound by English Law precedent, were not in a position to substantially modify riparian law or to adopt prior appropriation principles, such as those established by custom and judicially confirmed in the arid region of the U.S. southwest. Prior appropriation was based on a simple "first in time, first in right", principle. Thus, first comers were given priority in water-short situations and were assured water to sustain their operations provided such water was put to "beneficial use" and not wasted.

The riparian rights system of water law proved largely incapable of maximizing the economic potential of surface water in agricultural operations on the dry western plains. Percy (1977) in his article on water rights in Alberta has outlined this background and the events leading up to the enactment by Parliament of the Northwest Irrigation Act in 1894. This statute established the principle of prior appropriation through a system of licenses that has been continued in the present water rights legislation of the four western provinces and the Northwest Territories. Riparian rights were abolished or modified.

Water Use Regulation

The scheme of water rights legislation in the four western provinces and the two territories is similar. Property in water is vested in the Crown in right of each jurisdiction. The wording of these provisions differs, so that more or less of the pre-existing common law riparian rights have been abolished or modified in each jurisdiction.

All the statutes provide that water may be used only under a license from the designated water resources management authorities. The provincial statutes list water use purposes in order of precedence. For example, the Alberta Water Resources Act lists the following purposes in order of priority: domestic, municipal, irrigation and other agricultural, industrial, water power, and other.

There are no listed priorities in the federal Northern Inland Waters Act (1970), which applies to the territories. However, provision is made for classification of water uses and establishment of priorities by regulation. In all statutes, time priorities are established either on the basis of date of application filing or date of license issue. Uses licensed on the same date take precedence according to their ranking in the order of priority purposes. In periods of water shortage, licensed uses are accommodated according to their respective time and purpose priorities.

Each statute also contains a special provision for domestic use of water. Domestic uses are either excepted from each Act generally, or excepted from the licence requirement provisions. The Northern Inland Waters Act exception also included use of water for firefighting and emergency flood control purposes.

Use of water without a license or in excess of terms and conditions provided in a license is punishable as a quasi-criminal offence. Water management authorities in each jurisdiction also have powers in certain circumstances and subject to prescribed procedures to collect information, to inspect facilities, and if necessary to revoke or suspend licenses.

Major Water Projects

In Manitoba, Saskatchewan, and the Yukon and Northwest Territories, major water projects such as power dams and associated facilities are licensed under the water rights legislation discussed above. Alberta and British Columbia have additional statutory requirements for such projects.

The Alberta Hydro and Electric Energy Act requires application to the Energy Resources Conservation Board for construction permits and subsequently for operating licenses. The Board reviews each application, holds public hearings, and prepares a report and recommendation to the Lieutenant Governor in Council. Cabinet then decides whether or not to approve a proposed hydro-electric facility.

Recent legislative changes in British Columbia have established a public hearing and review process for "energy projects", including major water projects. The review is conducted by a panel of the British Columbia Utilities Commission. In Manitoba, the Water Commission may study and hold hearings on proposed water projects upon reference by the Minister.

Each of the jurisdictions also has established procedures for environmental impact assessment that are relevant to major water projects. For water power development, British Columbia's process is now formally embodied in the energy project review process. Other water projects may be assessed at the discretion of The Minister of The Environment under the Environmental Management Act. Alberta and Saskatchewan have statutory environmental assessment provisions that may be invoked through the exercise of ministerial discretion. Manitoba and the two federal territories have non-statutory guideline-type environmental assessment processes which may be applied to water projects. In the case of guideline processes, compliance with environmental assessment guidelines is obtained by exercise of the licencing powers under the water resources statutes.

Water Quality Regulation

All four Western provinces have legislation that establishes licensing systems for discharge of contaminants into water. Water pollution or discharge of water contaminants are prohibited in the absence of a license. Licenses are issued by pollution control authorities subject to guideline criteria that do not specifically form part of the statutes or regulation.

Alberta and Saskatchewan have separate water quality legislation. British Columbia's Pollution Control Act and Manitoba's Clean Environment Act regulate water contaminant discharges along with contamination of water and soil. In all cases, "stop orders" may be issued to halt polluting activities where, in the opinion of the management authorities, such action is necessary in the public interest. Such stop order action is subject to hearing or review as provided by each specific statute. In the Yukon and Northwest Territories, water-contaminating activities are governed by the Northern Inland Waters Act.

The Canada Water Act was originally intended to be the major federal water management statute, not only for the territories but for "inter-jurisdictional waters" that may be within the boundaries of provinces. Management agencies and management plans may be established in any designated management area. Other federal legislation, including the Northern Inland Waters Act, is designated to mesh with the Canada Water Act. However, apart from basin study agreements made under another part of the Act and phosphorous control regulation, the Canada Water Act has not been implemented. No water quality management areas have been established.

A third important federal water quality statute is the Fisheries Act. Unless provided for by regulation, it is an offence to deposit or permit the deposit of any "deleterious substance" in waters frequented by fish. Water quality standards have been established on an industry by industry basis. In addition, a form of environmental assessment is carried out under Fisheries Act authority that permits the Minister of the Environment to review and approve or disapprove any proposed works that are likely to produce such deleterious substances.

Finally, there are a number of federal and provincial statues aimed at renewable or non-renewable resource management, or at other specific activities that contain water pollution provisions. Examples include the pollution offences and regulations under the Canada Shipping Act, pollution provisions under the Alberta Oil and Gas Conservation Act Regulations, and pollution prohibitions under provincial Public Health Acts.

Present Legal Issues

In each of the jurisdictions uncertainty remains as to whether respective water rights statutes have completely abolished the basic riparian rights. If riparian rights remain, private water rights can be protected by judicial action even if water management agencies are reluctant to take action, and perhaps even in spite of licenses granted under legislation. Depending on ones view, either private rights or the integrity of water management plans may be at serious risk.

Percy (1977) is of the opinion that the Alberta Water Resources Act completely abolishes riparian rights. A similar view has been expressed of the B.C. Water Act, though it has also been argued that only the rights to water quantity, but not the right to receive water in an unpolluted condition (water quality), have been abolished. The Northern Inland Waters Act appears to preserve only the riparian rights associated with domestic use of water.

In addition to the basic riparian rights, the common law has developed certain "adjunct" rights. These include riparian owners' rights of access to water bodies, rights of navigation, ownership of the water bed, the doctrine of accretion, and principles applicable to land drainage. Another related doctrine that must be considered is the rule of capture associated with ground water.

Owners of riparian land are entitled to access to water as part of the right to the soil itself. A right to access does not require ownership of the water bed. Rights of access exist on navigable rivers, for example. Since the rights to water frontage and access are not specifically mentioned in any of the water rights statutes, these rights continue and are unaffected by the legislation. This is in spite of provisions in water rights or public lands statutes that vest all water beds in the Crown.

Historically, in English common law a public right of navigation developed. This permitted any member of the public to navigate without hindrance or obstruction in navigable, tidal waters, despite the fact that the bed of such waters may be privately owned. Canadian courts extended this public right of navigation to include non-tidal waters that are in fact navigable.

The federal government has exclusive legislative jurisdiction in relation to navigation and shipping under the British North America Act. Under this power the federal government has enacted the Navigable Waters Protection Act which authorizes the Ministry of Transport to regulate works and other obstructions in, on, over, or under navigable waters.

Land drainage is an area in which courts of the western provinces have moved in different directions. The English Common Law applied the riparian principle that gave a lower riparian owner the right to receive water unincreased in flow, to all land drainage situations. Thus a lower land owner was entitled to erect works to hold surface water on the upper land. This rule was applied by Ontario courts and affirmed by the Supreme Court of Canada. It has also been adopted by courts in Manitoba and British Columbia.

However, Alberta courts have consistently refused to follow the English rule. The Alberta Court of Appeal has held (in 1917) that a lower landowner is bound to permit surface waters from rain or snowmelt to drain onto his land, unless such drainage is artifically increased by his neighbour. The Court took the unusual step of holding that the English rule never became part of the law of Alberta because of its inapplicability to Alberta conditions. This "Alberta Doctrine" has been applied by the Alberta Supreme Court as recently as 1975. Whether it applies in Saskatchewan and the northern territories is an open question.

Historically, a different set of legal principles was developed for ground water, as opposed to surface water flowing in defined streams. Nineteenth century English cases determined that ground water allocation should be based not on riparian rights but on a "rule of capture". Ground water could be used without restricion by a landowner even though this use may adversely affect the supply of adjoining landowners. Ground water is now covered in the statutory licensing provisions in all jurisdictions except British Columbia. There the Water Act contains an as yet unused power in the Cabinet to extend the provisions of the Act to ground water by proclamation. Some provinces, such as Alberta, have separate statutes that provide for ground-water management and regulate well-drillers.

There is an apparent problem concerning ground-water allocation under statutory licensing systems. It stems from the fact that where ground-water users are unlicensed or exceed license terms, other users damaged by such activities may be forced to rely on the common law to provide a remedy.

This is illustrated by the 1967 Alberta Case, Schneider v. Town of Olds. Schneider used ground water for domestic purposes under the Water Rights Act. He held no water license. Olds drilled a well nearby that adversely affected his water supply. Schneider's action against the Town was dismissed despite the fact that Olds had exceeded the terms of its water license in drilling and producing its well. He could recover no damages because at common law under the rule of capture he had suffered no loss. His only remedy, said Chief Justice Milvain, was to persuade or, perhaps by legal action, require the provincial Water Rights officials to correct the situation. Thus, despite the licencing system and the express domestic use protection, ground-water users who suffer reduced supply or additional pumping costs may be without legal protection.

For a review of legal aspects of the ownership of beds of water bodies, water boundaries, and changes of property due to erosion or sedimentation, see Lucas (1981).

Under the BNA Act, Canada has legislative power in relation to "Indians and Lands Reserved For the Indians". Indian title in the four western provinces and the territories is substantially affected by the Proclamation of 1773, which reserved large areas for the use of the Indians, and by 1930 Natural Resources Transfer Agreements. In Calder v. A.G. BC(1974), the Supreme Court of Canada split 3-3 on the question of the existence of aboriginal title. The weight of authority suggests that aboriginal title does indeed exist. However the exact nature of Indian title has never been judicially defined. There are indications, for example in the recent Baker Lake Case (Federal Court, 1979), that aboriginal title is related to way of life, so that it is essentially limited to rights to use land for hunting, fishing, and trapping.

But there are arguments to suggest that aboriginal title includes land and water resources, and that it may even enjoy a constitutionally protected status, including immunity from expropriation.

Indian lands in much of the four western provinces and a portion of the territories were surrendered to the Crown in return for designated reserves and specified compensation. The essential legality of particular treaties may be questioned on the basis, for example, that because the signing chiefs did not fully understand the nature of the transaction, there was no legal consensus. In general these surrendered areas, including their water rights, may be treated as ordinary Crown lands.

However, Indian title remains in areas that were not subject to treaty, including property interests such as water rights. These areas are now the subject of land claims by native people. In the territories, land claims negotiations between the federal government and native representatives are in progress. The native positions include native resource ownership as well as native land and water planning and management authority.

For Indian reserves, while beneficial title is vested in the Indians, the powers of administration and management are, under the BNA Act and the Indian Act, vested in the federal government. The underlying legal title for most western Canadian reserves is also vested in Canada rather than the province. Consequently, federal cooperative action, as well as Indian approval, is required for provincially initiated water development that involves Indian lands. Like the treaties, it is possible that early agreements concerning water facilities contain legal weaknesses that may be raised. For example, this possibliity was considered during the recent dispute between the Peigan tribe and a local Irrigation District concerning irrigation works on reserve lands in southern Alberta.

Certain difficult legal problems are posed by major water projects such as dams for electrical generation or storage and flood control purposes. In the western provinces there are no clear guarantees that proposed water projects will be subjected to detailed public review processes. The Alberta Water Resources Act requires that persons likely to be affected be given notice and an opportunity to file written objections. A hearing may be held by water rights officials, but this is a matter of discretion. A hydro-electric project will be the subject of a hearing before the Energy Resources Conservation Board, and Cabinet approval must be confirmed by a bill which will be debated in the legislature. An environmental impact assessment may be required for major projects, but this is at the discretion of the Minister of the Environment. The Alberta government has approved major works on the Red Deer, Oldman, and Slave Rivers without first requiring environmental assessments.

In British Columbia, energy projects may be subjected to full environmental assessment including public hearings by the Utilities Commissions. The Environmental Management Act, enacted in 1981, gives the Minister of the Environment discretion to require environmental assessments of non-energy water projects. Saskatchewan's statutory and Manitoba's guideline environmental impact assessment processes are also discretionary. In the Territories, a public hearing would be required by the Territorial Water Boards as part of the water license acquisition process, but only if objections to the license application were received.

The possiblilty of compensation for damage caused by a water project depends first on the nature of the interest affected. Compensaton may be available only for legally recognized interests. Thus, holders of license or permit interests, such as registered traplines or fishing interests, may have no legal right to compensation if the animals or fish upon which the license depends are damaged. This was a major obstacle to recovery of damages by Peace- Athabasca delta Indians and Metis when water level changes caused by the W.A.C. Bennett Dam in B.C. resulted in substantial reductions in delta fish and wildlife populations.

Unless an individual has a direct interest, only the government is legally able to bring public actions or to authorize privately initiated suits. The problem is that government is usually involved in major water projects as developer or promoter. This potential "conflict of interest" situation has been extensively discussed in the environmental law literature. A solution often proposed is an "environmental bill of rights" that specifically guarantees private individuals and organizations legal status to bring actions aimed at protection of public resources, including water resources.

Direct harm, such as water pollution, may be compensable through private legal actions. But major water projects may be protected by statutory authority. That is, the developers of the water project may have a defence against actions for damage that is the inevitable result of the project.

Where damage in one jurisdiction is caused by a water development located in a neighboring jurisdiction, procedural and possibly substantive legal problems may make damage recovery difficult. For example, the law on which jurisdiction is the proper forum for legal action in this situation is not completely clear. Nor is it clear which jurisdicton's common and statute law should be applied, although the Supreme Court of Canada has ruled in Interprovincial Co-operatives and Dryden Chemicals Ltd. v. The Crown in Right of Manitoba that statutory approvals in one province should not be construed to deprive individuals in another province of property or other rights. There is no interprovincial water law, despite reasoning that may lead to this conclusion by Mr. Justice Pigeon in the Interprovincial Co-operatives case.

With the development of extensive and detailed water management regimes under provincial statutes and under the Northern Inland Waters Act, a set of legal issues has developed around the question of the extent of water management authorities' powers under the statutes and regulations. One area concerns the powers of water rights officials in relation to individual landowners or water users.

One aspect of this problem, namely the extent of private rights to compensation for damages arising out of water projects, has been discussed. Another area that has been briefly mentioned is the rights of individuals to notice and opportunities to participate in water management decisions. Put another way, the issue here is fair treatment for persons affected by water decisions.

A different jurisdictional problem has arisen in the Northwest Territories under the Northern Inland Waters Act. The issue there is the extent to which water uses that require licenses by the Territorial Water Board can be approved by "authorization" of the staff controller under regulations, thus avoiding Water Board hearing and review. This problem is compounded by the fact that the Water Board members are appointed by the Minister of Indian Affairs and Northern Development (DIAND) upon the nomination of concerned Federal departments (Environment, Transport, etc), and The Commissioner in Council of the Territory (the territorial government), while the controller is a staff member of DIAND. The Board is in the position of, in effect, not having ultimate control over its senior staff member. There is a strong argument that authorizations by the controller must be supplementary and subordinate to the main Water Board licensing power in the Act. Both sides have obtained legal opinions, and negotiations aimed at resolving the dispute are now underway. Legal action on this same issue has been initiated in the Yukon Territory.

Another problem of jurisdiction arises when water rights licensing procedures are viewed against other statutory approval processes to which projects involving major water use are subject. For example, water is a major issue in oil sands plant applications. Under the Alberta coordinated approval process, the hearing body of these applications is the Energy Resources Conservation Board. The Board, with the addition of a seconded member from the Department of the Environment, holds hearings that include water issues. But the Board has no authority to either issue water licenses or to lay down requirements for water license conditions. That is for the Environment department.

Water management legislation in all of the western Canadian jurisdictions has placed substantial discretionary water management powers in the hands of government managers or administrative agencies. Clearly, exercise of these powers affects private decision-making. As we have seen, private common law rights, as well as rights conferred by the statutes themselves, are also affected.

A serious question can be asked about the appropriateness of vesting all of these powers in government agencies. There is a potential conflict of interest when government acts as developer as well as regulator. There may also be doubts about the ability of water rights officials to consistently act in a procedurally fair manner. All of this suggests the possibility that there may be a greater water rights decision-making role for the courts.

Courts have been active in water rights adjudication in the western United States. In many states judicial dispute resolution is considered an integral part of the water rights system. Canadian courts have not been given the same role by the water management statutes, nor have Canadians traditionally been as litigious as their U.S. counterparts. However, as water supply problems mount and as pressure on water management agencies increases, it is possible that western Canadians may also turn to the courts for greater assistance in resolving water disputes.

Perhaps the major area of current constitutional conflict relevant to water concerns federal powers in relation to fishery protection and provincial jurisdiction arising from ownership and management of public resources. Two Supreme Court of Canada cases in 1980 have been decided on the question of how far federal fisheries laws can affect provincially regulated forestry operations. The result of the cases is that the Dominion cannot enact fishery protection provisions so broad that they have the effect of directly regulating natural resource development operations within the province.

The issue of whether provincial water management law requirements may be validly applied to interprovincial pipelines arose in the fall of 1980 in relation to the Alaska Natural Gas Pipeline. British Columbia officials issued authorizations under the Water Act that required flumed crossings of certain rivers. The federal Northern Pipeline Agency (NPA) ordered Foothills Pipe Line Ltd. to carry out studies of the impact of instream crossings and of the practicability and cost of flumed crossings. Subsequently, after reviewing these studies, the NPA ordered Foothills to proceed with instream crossings.

The B.C. Attorney General applied for and was granted a temporary injunction prohibiting the Company from proceeding with certain river crossings other than in accordance with B.C. requirements. The main issue for the trial was the constitutional authority of British Columbia to apply its water management requirements to an extraprovincial undertaking that under the BNA Act is subject to exclusive federal jurisdiction. In the result, weather conditions and time constraints caused B.C. water rights officials to revise their original requirements. Instream crossings were then approved, subject to certain conditions. However, this confrontation squarely presents the question of whether provincial water management requirements can be enforced against federally regulated activities such as pipelines and railways. There is no direct judicial guidance. However, there is a strong likelihood that the provincial water legislation would be held applicable.

Difficult and largely unresolved constitutional problems remain with respect to regulation of interprovincial waters. There is a special problem when governments or their non-arms-length Crown Corporations are water developers. It is no longer a matter of private rights resolution. The parties are sovereign law-making bodies. Consequently, which law to apply is again a problem. Such actions will be tried in the Federal Court since the Dominion, and all provinces except Quebec have passed reciprocal legislation to give that court jurisdiction.

All the judges in the Interprovincial Cooperatives Case mentioned earlier agreed that control of pollution in interprovincial rivers is a matter within exclusive federal jurisdiction. Very likely this authority is sufficient support for the Canada Water Act powers to establish water quality management agencies for interjurisdictional waters. But the extent of this federal jurisdiction has not been clarified, and it remains largely unexercised.

It has been argued that water development on interprovincial and international rivers is also within federal jurisdiction. This might be on the basis that such waters are matters of national concern under the Peace Order and Good Government power, or that interjurisdictional developments are extraprovincial undertakings within the BNA Act. There is no direct authority, but it is doubtful that this view would be sustained. Actual federal water development regulation, including authority to plan and to decide what water resources to develop and in what time frame, cuts too deeply into constitutionally guaranteed provincial resource ownership and provincial powers over management of public lands.

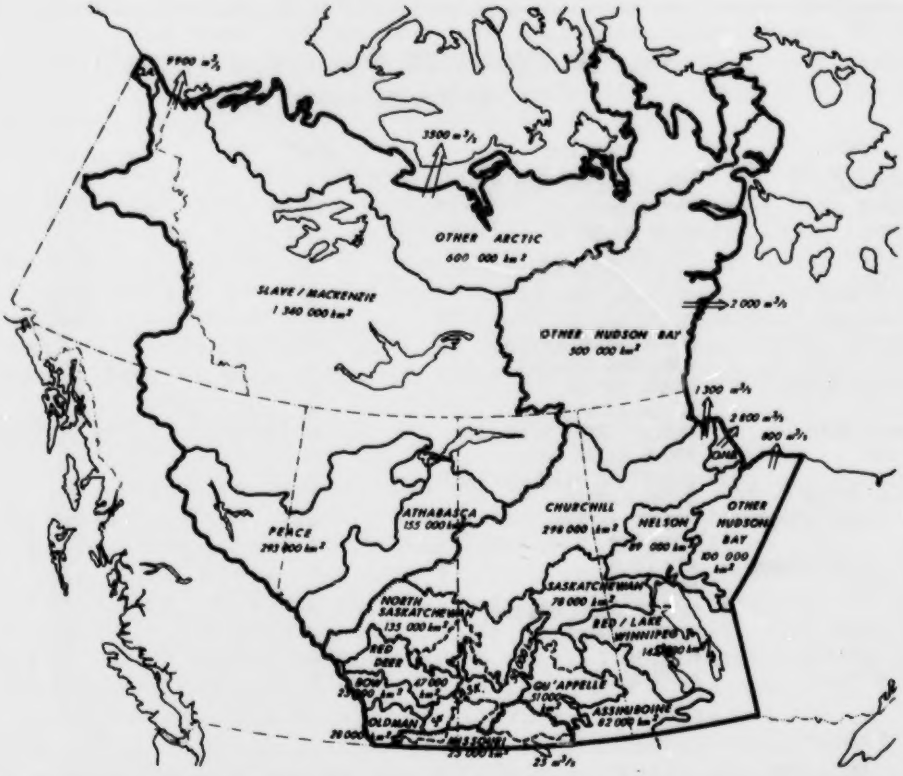
All of the areas discussed - fisheries, forestry, water management, interprovincial works, and interprovincial waters - show significant shared federal and provincial jurisdiction. As a practical matter this underlines the need for federal-provincial cooperation in these areas, as through the Prairie Provinces Water Board.

CHAPTER II

WATER IN THE STUDY REGION

1. THE SURFACE HYDROLOGY

Figure 16. DRAINAGE BASINS CONSIDERED IN THIS STUDY, AND THEIR AREAS.


9900 m³/s
3500 m³/s
OTHER ARCTIC
600 000 km²
SLAVE / MACKENZIE
1 340 000 km²
2 000 m³/s
OTHER HUDSON BAY
500 000 km²
1 300 m³/s
2 800 m³/s
800 m³/s
PEACE
293 000 km²
ATHABASCA
155 000 km²
CHURCHILL
298 000 km²
NELSON
89 000 km²
OTHER HUDSON BAY
100 000 km²
SASKATCHEWAN
78 000 km²
NORTH SASKATCHEWAN
135 000 km²
RED DEER
BOW
km²
47 000 km²
SK.
RED / LAKE WINNIPEG
QU'APPELLE
51 000 km²
ASSINIBOINE
82 000 km²
OLDMAN
28 000 km²
MISSOURI
25 000 km²
25 m³/s

==

Waters draining from western Canada flow to five marine bodies: the Pacific Ocean, the Bering Sea, the Arctic Ocean, Hudson Bay, and the Gulf of Mexico. The first two receive the outflow of the drainage west of the Great Divide, from the Fraser, Columbia, Yukon, and other rivers in coastal and northwestern British Columbia. Those systems are not included in this study.

A list of major rivers in the Study Region, some of them tributary to others, is found in Table 13, in order of recorded average flow rates near their mouths. A map of the 17 drainage basins studied, with their areas; and a map of the major rivers, with their mean computed natural discharges (see appendix for definitions), are contained in Figures 16 and 17.

TABLE 13. RECORDED MEAN ANNUAL FLOWS OF SELECTED RIVERS
(ENVIRONMENT CANADA, 1980A)

RIVER	LOCATION	R/N*	FLOW (M^3/S)**
MACKENZIE	ABOVE ARCTIC RED R.	R	9630
SLAVE	FITZGERALD	R	3520
LIARD	NEAR MOUTH	N	2580
NELSON	KELSEY	R	2400
PEACE	PEACE POINT	R	2070
CHURCHILL	RED HEAD RAPIDS	R	1080
WINNIPEG	SLAVE FALLS	R	840
THELON	ABOVE BAKER LAKE	N	785
ATHABASCA	EMBARRAS AIRPORT	N	785
SASKATCHEWAN	GRAND RAPIDS	R	690
HAYES	BELOW GODS R.	N	630
GREAT BEAR	OUTLET GREAT BEAR LAKE	N	540
KAZAN	ABOVE KAZAN FALLS	N	410
REINDEER	OUTLET OF REINDEER LAKE	R	320
FOND DU LAC	STONY RAPIDS	N	300
N. SASKATCHEWAN	PRINCE ALBERT	R	245
RED	LOCKPORT	R	240
S. SASKATCHEWAN	ST. LOUIS	R	220
OLDMAN	NEAR MOUTH	R	110
BOW	BELOW CARSELAND DAM	R	110
RED DEER	NEAR EMPRESS	R	70
ASSINIBOINE	HEADINGLY	R	50
QU'APPELLE	NEAR WELBY	R	10

*N - NATURAL

R - REGULATED

**PERIODS OF RECORD VARY CONSIDERABLY

Arctic Ocean

Drainage to the Arctic Ocean is principally the outflow to the Beaufort Sea from the Mackenzie River. A number of smaller coastal basins also drain to the Beaufort Sea or to the several gulfs which make up the southern shore of the Arctic Ocean.

The total surface area drained to the Arctic Ocean from mainland Canada is 2 400 000 km^2, about 25 percent of the area of Canada. The major river system is the Slave River/Mackenzie River complex, with its largest tributaries, the Athabasca, Peace, and Liard Rivers. The greatest river length is the Peace/Slave/Mackenzie combination, about 4200 km; while the Athabasca/Slave/ Mackenzie combination reaches about 3800 km in length. The total discharge to the Mackenzie delta (about 10 700 m^3/s) rivals that of the Great Lakes/St. Lawrence River system (about 10 100 m^3/s). The total discharge to the Arctic Ocean, including the other basins, is about 13 400 m^3/s.

The Arctic drainage basin contains some of the world's largest natural lakes. In surface area, Great Bear Lake ranks ninth in the world (31 300 km^2), Great Slave Lake ranks eleventh (28 600 km^2), and Lake Athabasca is twenty-fifth (8 000 km^2). These three are the third, fourth, and eighth largest lakes in Canada. The world's ninth largest man-made reservoir, Williston Lake (1 660 km^2), formed by the W.A.C. Bennett Dam, is located on the Peace River in British Columbia.

Hudson Bay

Drainage to Hudson Bay is mainly from the Saskatchewan/Nelson system, which includes the North Saskatchewan, Oldman, Bow, Red Deer, and South Saskatchewan Rivers, all of which rise on the east slopes of the Rocky Mountains. Other important tributaries, rising on the Interior Plains, are the Battle, Qu'Appelle, Assiniboine, Souris, and Red Rivers. The Winnipeg River, which rises in the Canadian Shield, originates outside the Study Region in Ontario. The total drainage of the Saskatchewan/Nelson system covers 1 132 000 km^2, of which 148 000 km^2 is in the United States. The greatest river length to be found in the Saskatchewan/Nelson system is the over 3000 km from the headwaters of the Bow River to Hudson Bay.

The second largest system flowing to Hudson Bay from the Study Region is the Beaver/Churchill, which drains nearly 300 000 km^2 from eastern Alberta across northern Saskatchewan and Manitoba. In 1976, the Churchill River was connected to the Nelson River by a diversion to the Rat and Burntwood Rivers. The combined annual discharge of the Saskatchewan/Nelson and the Churchill systems is about 4100 m^3/s, less than one-half that of the Mackenzie River drainage.

North of the Churchill River, several smaller river basins drain to the northwestern corner of Hudson Bay from the Thelon system (230 000 km^2). There also exists a lowlands drainage region encompassing the shoreline around western Hudson Bay, both north and southeast of the Nelson-Churchill systems.

The Hudson Bay drainage also contains some of the world's largest lakes. Lake Winnipeg is ranked fourteenth at 24 350 km^2, while Reindeer, Winnipegosis and Manitoba have surface areas between 4500 and 6500 km^2. The largest entirely man-made reservoir in this region is Lake Diefenbaker (430 km^2) on the South Saskatchewan River, formed by the Gardiner and Qu'Appelle River Dams.

Gulf of Mexico

The drainage to the Gulf of Mexico from Canada consists of a small contribution to the Missouri River from southern Alberta and Saskatchewan, flowing from a surface area of about 26 000 km^2. The principal conveyance is the Milk River, which rises in the United States but traverses north of the international boundary in Alberta before bending southward back into Montana.

Extent of Water

In addition to the very large lakes found in the Study Region, countless smaller lakes exist. All are described in terms of their area in relation to total land area in Table 14. These figures, which include all of the Yukon Territory, do not include many thousands of small lakes, ponds, and temporary water bodies. Environment Canada (1975) estimates that approximately 7500 small water bodies exist just in a 13 700 km^2 area southwest of Reindeer Lake in Saskatchewan.

The Study Region contains several closed drainage areas that do not drain to other basins or to the sea. These are identified in Figure 16 and in some cases are quite large (see Table 21).

Although considerable data concerning ground water exist for the southern portions of the prairie provinces, very few exist for the Mackenzie and other northern drainage basins. Specific information on ground water is provided in Sections II.5, III.4, and V.4.

TABLE 14. APPROXIMATE LAND AND FRESH WATER AREAS, BY PROVINCE
(STATISTICS CANADA, 1978A)

PROVINCE OR TERRITORY	LAND KM^2	FRESHWATER KM^2	TOTAL KM^2
MANITOBA	548 495	101 592	650 087
SASKATCHEWAN	570 269	82 631	651 900
ALBERTA	644 389	16 796	661 185
BRITISH COLUMBIA[1.]	930 528	18 068	948 596
YUKON TERRITORY [1.]	478 034	4 481	482 515
NORTHWEST TERRITORIES			
FRANKLIN	1 403 134	19 425	1 422 559
KEEWATIN	565 809	25 123	590 932
MACKENZIE	1 277 447	88 746	1 366 193

1. STATISTICS ARE FOR THE WHOLE PROVINCE/TERRITORY AND THEREFORE INCLUDE LAND AND WATER OUTSIDE THE STUDY REGION.

The amount of water stored in all the glaciers of western Canada is unknown because of the difficulty of measuring this value and because annual variations in ice volumes are large. Environment Canada (1975) claims that all the water stored in glaciers in North America greatly exceeds that stored in all the lakes, ponds, rivers, and reservoirs on the continent.

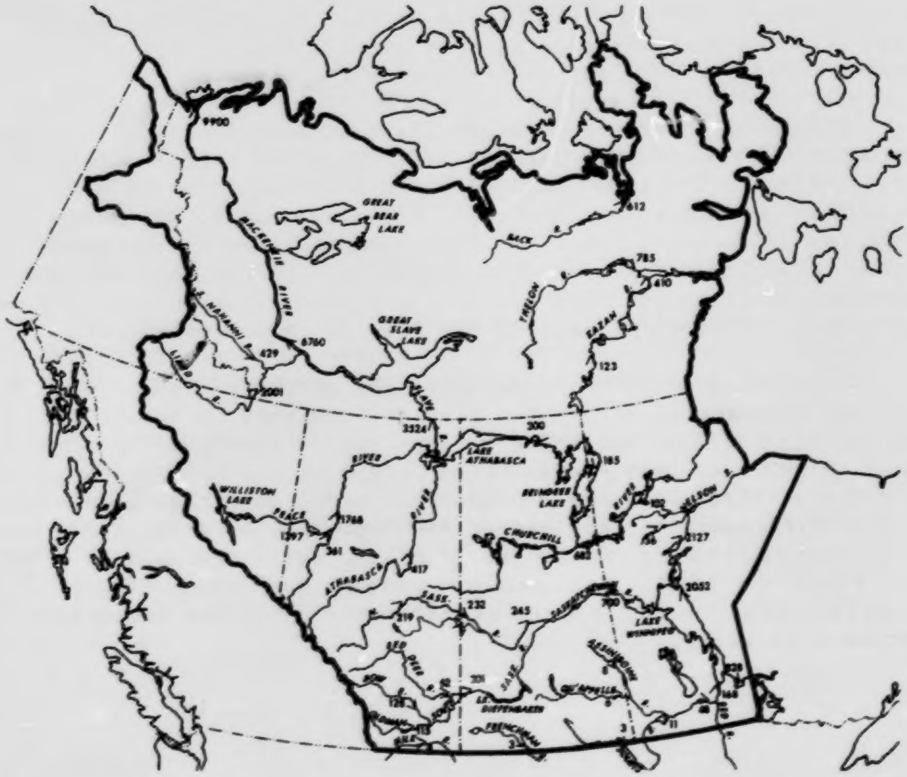
Glaciers in Western Canada are important features, not just because of their water content but because of their influence on streamflow. Streams with glacier-fed headwaters have greater seasonal consistency and fewer anomalies in discharge than streams that originate on the plains. The Saskatchewan and Athabasca Rivers are two good examples. During some hot summer months, meltwater from glaciers and snow lying on glaciers may contribute up to 25 percent of the flow of these two rivers.

The large river discharge to the north, as compared to the volume discharging across the prairie provinces to Hudson Bay, is frequently cited as being a disparity of supply in relation to need. For example, annual drainage volume per capita in the Northwest Territories is about 25 times more than in Alberta. The significance of this comparison depends upon assumptions that the importance or value of surface water drainage is solely related to local per capita usage, and that there is a consistency in per capita requirements. Neither assumption is necessarily valid.

It may be more significant to draw such comparisons more locally. The southern portion of Alberta has about 20 percent of the province's total supply, and about 80 percent of the need. The term "need" is again, however, subject to opinions which vary. The comparison of predominantly instream needs, such as the preservation of the deltas of the northern rivers or maintenance of flows for navigation, with the predominantly offstream needs of the dry, populated southern regions is a difficult challenge for water managers.

The eastern Cordillera is the most important source of streamflow for the prairie provinces. Approximately 70 percent of the streamflow in wet years, and 90 percent in dry years, of the North and South Saskatchewan River basins originates in the eastern Cordillera, which has only 15 percent of the total drainage area (Laycock, 1957). The Plains region, in contrast, contributes very little to the total streamflow.

Figure 17. MAJOR RIVERS IN THE STUDY REGION, AND MEAN ANNUAL NATURAL FLOW RATES (m^3/s) AT SELECTED POINTS (WER, 1980a; Environment Canada, 1980a).


9900
GREAT BEAR LAKE
MACKENZIE RIVER
612
BACK R.
785
410
THELON
KAZAN
123
GREAT SLAVE LAKE
6760
S. NAHANNI R.
429
LIARD R.
2001
SLAVE
3324
300
LAKE ATHABASCA
185
REINDEER LAKE
RIVER
WILLISTON LAKE
PEACE
1768
1397
361
RIVER
ATHABASCA
417
CHURCHILL
682
RIVER
NELSON R.
2127
2052
SASK.
232
245
SASKATCHEWAN R.
700
LAKE WINNIPEG
219
RED DEER R.
BOW R.
126
OLDMAN
113
MILK
92
331
SASK.
LK. DIEFENBAKER
FRENCHMAN
3
QU'APPELLE R.
ASSINIBOINE R.
3
11
48
160
228

The average annual streamflows of the major rivers in the Study Region are shown in Figure 17. Most of the data are recorded at gauging stations maintained by the Inland Waters Directorate of Environment Canada, although many are partially or wholly funded by provincial and territorial water agencies. The standard method employed at these stations for measuring streamflow is to measure the water level (stage) and convert this to discharge by means of a "stage-discharge" curve.

The extent to which precipitation reaching the drainage basins in the Study Region eventually reaches the streamflow network depends upon drainage efficiencies. It has been estimated that the effective drainage area in the dry southern portions of the Study Region ranges from 20 to 40 percent of the gross drainage area (see Chapter II). The balance consists of small closed water bodies (e.g., sloughs) where drainage evaporates, sinks to ground-water bodies, or contributes as runoff during above-average floods.

A more technical guide to hydrologic processes and definitions describing ways of presenting streamflow statistics are contained in the Appendix.

2. INTERBASIN TRANSFERS

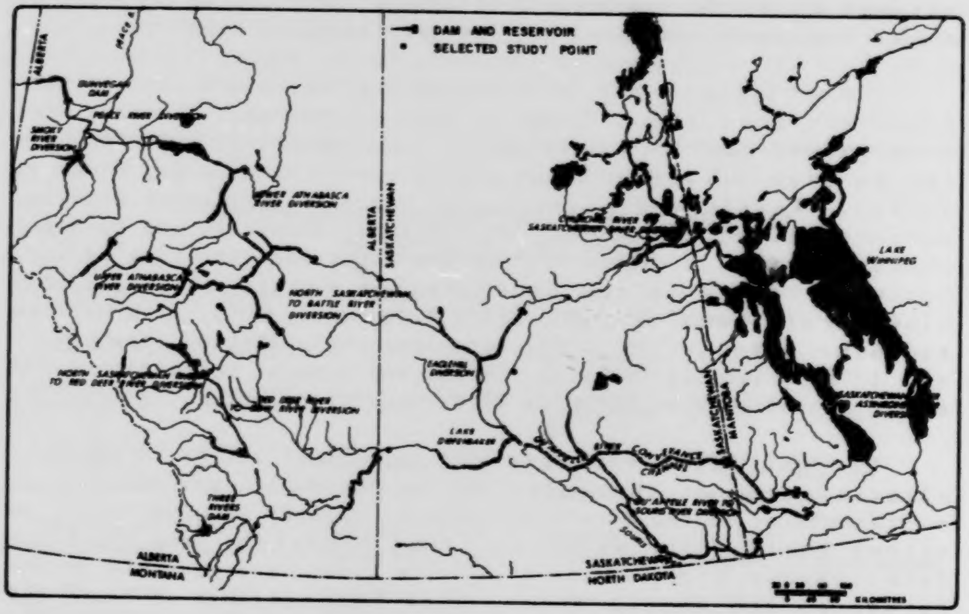
The distribution and quality of water do not always coincide with the demands placed upon it at any given time and place. As the economy of a region develops, discrepancies can become serious if development is not sensitive to the amount and quality of available water.

Supply aspects can be addressed by artificially altering the natural supply, either by increasing or decreasing streamflows, seasonally or over a longer term basis. This can be accomplished, to a degree, by works which regulate the natural streamflow in a basin. In the Study Region, excepting for most northern rivers and some mountain streams, virtually all major rivers are affected by regulation.

In cases where even the most efficient regulation within a basin is not sufficient to provide appropriate quantities of water, consideration can be given to interbasin transfer, the artificial diversion of water from one drainage basin (the donor basin) to another (the receiving basin). This can include atmospheric water transfers induced by cloud seeding and cloud cover alteration, but the most practical and controllable interbasin transfers are those involving surface waters. Ground-water transfers could be induced by excessive pumping of an aquifer.

The first large-scale transfers in the Study Region occurred with the settlement of the dry southern prairie near the turn of the century, primarily to facilitate irrigation. Today, major interbasin transfers exist which vary in both purpose and size. The diversion from the Churchill River to the Nelson River in northern Manitoba transfers hundreds of cubic meters of water per second on a continuous basis to hydro-electric sites in the receiving basin. The Portage Diversion from the Assiniboine River to Lake Manitoba operates intermittently to divert flood waters. The transfer from the South Saskatchewan River (Lake Diefenbaker) to the Qu'Appelle River serves various uses, primarily municipal supply and water quality improvement. Other transfers operate seasonally to carry somewhat smaller quantities of water over great distances to service irrigation farmers. The benefits of these and other transfers have been considered to be economically and/or politically sufficient to justify the direct and indirect, tangible and intangible, costs. The Saskatchewan-Nelson Basin Board (1972) has provided the most in-depth analysis of possibilities for interbasin transfers in the Study Region.

Figure 18. THE MOST SUCCESSFUL COMBINATION OF NEW DAMS, RESERVOIRS, AND DIVERSIONS EVALUATED BY THE SNBB (1972).


DAM AND RESERVOIR
SELECTED STUDY POINT
ALBERTA
PEACE R.
DUNVEGAN DAM
PEACE RIVER DIVERSION
SMOKY RIVER DIVERSION
LOWER ATHABASCA RIVER DIVERSION
UPPER ATHABASCA RIVER DIVERSION
NORTH SASKATCHEWAN TO BATTLE RIVER DIVERSION
NORTH SASKATCHEWAN RIVER TO RED DEER RIVER DIVERSION
RED DEER RIVER TO BATTLE RIVER DIVERSION
THREE RIVERS DAM
ALBERTA
MONTANA
ALBERTA
SASKATCHEWAN
EAGLEHILL DIVERSION
LAKE DIEFENBAKER
CHURCHILL RIVER TO SASKATCHEWAN RIVER DIVERSION
LAKE WINNIPEG
QU'APPELLE RIVER CONVEYANCE CHANNEL
SASKATCHEWAN
MANITOBA
SASKATCHEWAN TO ASSINIBOINE DIVERSION
QU'APPELLE RIVER TO SOURIS RIVER DIVERSION
SOURIS
SASKATCHEWAN
NORTH DAKOTA
KILOMETRES

At present no surface transfers exist in Canada between continental drainage basins (i.e., Pacific, Arctic, Hudson Bay, and Gulf of Mexico basins), although some have been considered. The McGregor (Pacific-Arctic) and Garrison (Gulf of Mexico-Hudson Bay) Diversions are presently deferred or suspended. Proposals have been made for larger, even North American, projects, some of which look to the waters of the Mackenzie River basin as a source of supply for the south.

Interbasin transfer is not always considered to be either the best solution to supply/demand problems, or of net benefit. Alternatives to "supply" solutions have been suggested by Tate (1980): limiting developments that are not compatible with existing supply; rationing, pricing, and scheduling water uses; and increasing use efficiency.

The determination of net benefit or disadvantage can be a complex undertaking, involving economic, technical, social, legal, environmental, and political factors. Benefits may be identified in terms of direct and indirect economic development, savings due to the suppression of damages by flooding or drought, and/or improvement of water quality or biological habitat.

Disadvantages may be less easily determined. Interbasin transfers result in a change to natural systems. Concerns have been raised that the environmental consequences of major changes can be significant and not always predictable (e.g., Newbury, 1979a). Possible damages could result from altered erosion, sedimentation, biological, ice, thermal, chemical, and climatic characteristics in either or both the donor and receiving basins. Concerns raised in the Study Region relate to undesirable biological transfer (IJC, 1977; B.C. Hydro, 1978; Alberta Fish and Game Association, 1980), erosion/ sedimentation (Newbury et al, 1978), climatic (Findlay, 1981), and general recreational and environmental aspects (Alberta Wilderness Association, 1980).

Economic disadvantages can be related either to the cost effectiveness of the solution to the major problem(s) being addressed, or to the direct or indirect effects on other uses, in either basin. For example, water transfers from the South Saskatchewan River to the Qu'Appelle River, and possibly in the future to the Souris River, have identifiable economic and environmental benefits (QBSB, 1972; SRBSB, 1978), but these could be offset or limited by disbenefits due to reduced hydro-electric generation in the South Saskatchewan and Saskatchewan River basins. Also, Billing (1980) has described possible disbenefits (impacts on uses, native land claims) in the Mackenzie River basin, should it become a donor element of an interbasin transfer.

Because of their water management mandate, the provinces would be the originators of interbasin transfer proposals south of 60° North. Federal involvement would occur where national interest, federal funding, interjurisdictional effects, or specific federal responsibilities (e.g., fisheries, navigable waters, federal lands) are involved, or where there is a request from the provinces.

Discussion of major interbasin transfers sometimes leads to the topic of export of water to the United States from Canada. The policies of the governments of Canada, Saskatchewan, and Alberta are that these governments will not enter into discussions of water export.

A description of specific interbasin transfers follows. For the purposes of this report, only surface transfers that are considered to be of significance to the supply of the 17 Study Region basins are included (Table 15).

TABLE 15 **EXISTING AND POTENTIAL INTERBASIN WATER TRANSFERS AFFECTING THE STUDY REGION**

INTERBASIN TRANSFER	DONOR BASIN	RECEIVER BASIN	YEAR EST'D	PURPOSE(S)	CAPACITY	REMARKS
S. Sask. R. Project	S. Sask. R.	Qu' Appelle R.	1967	Municipal supply and water quality	12 m^3/s	
Water Supply for the Souris River Basin	S. Sask. R. Assiniboine R.	Souris R. Souris R.	No Action	Municipal and industrial supply	10-45 m^3/s 3-30 m^3/s	Unnecessary or uneconomic for foreseeable future
S. Alta. Irrigation Projects	Bow R.	Red Deer and Oldman Rivers	1900 to 1920	Irrigation	See Table 17	During irrigation season only
Portage Diversion	Assiniboine R.	L. Manitoba	1970	Flood control	708 m^3/s	Used during extreme flood periods only
Churchill Diversion	Churchill R.	Nelson R.	1976	Hydro power	850 m^3/s	
Garrison Diversion Unit	Missouri R.	Souris & Red Rivers	Suspended	Irrigation, etc.	34 m^3/s	Partially constructed
Root River Diversion	Albany R.	Winnipeg R.	1957	Hydro power	85 m^3/s	
Cold Lake Project	N. Sask. R.	Beaver R.	Project Suspended	Oil Sands Development	1 m^3/s	Alternatives to this transfer are being investigated
McGregor River Diversion	Fraser R.	Peace R.	Suspended	Hydro power and flood control	< 200 m^3/s	

Water Supply for the Saskatchewan-Nelson Basin

During the 1960s, concern over future water shortages in the Saskatchewan-Nelson basin led the governments of Canada, Alberta, Saskatchewan, and Manitoba to consider preparing comprehensive plans for water use. As a first step, it was agreed to study the water supply of the basin, including the potential additional supply available through diversion and storage. (A study of historical and present water use in the Saskatchewan-Nelson basin is now being undertaken by the PPWB.)

The Saskatchewan-Nelson Basin Board (SNBB) was formed and directed "...to study the engineering feasibility and cost of storage and diversion works needed to provide a firm water supply of varying amounts at various selected points along the river system" (SNBB, 1972). An inventory of the existing supply was made and 55 dam and 23 diversion possibilities were investigated. These projects represented some of the best possibilities for regulating and augmenting the supply. 'Guaranteed flow' was used as a measure of flow improvement, and the year 1941, a very low flow year under natural conditions, was chosen to test project effects.

The principal finding of the study was that, with major expenditures, large supplies of water could be made available for use throughout the basin. The most successful of the many project combinations that were tried (in that it gave the greatest increase in supply to most parts of the basin) included eight new reservoirs, numerous interbasin transfers within the basin, and transfers of water from the Peace, Athabasca, and Churchill Rivers (see Figure 18). It was assumed that a diversion rate of 850 m^3/s would be possible from the Peace-Athabasca system and 280 m^3/s from the Churchill. Diversions within the Saskatchewan-Nelson basin ranged in magnitude from 20 m^3/s to 420 m^3/s. With these projects in operation, Alberta and Saskatchewan could withdraw all waters allocated under the Master Agreement on Apportionment (Chapter I), and the remaining flows would be above the suggested minimum flows (set by the provinces) for the various points in the basin. The flows that could be guaranteed at each selected study point are listed in Table 16.

Little attempt was made to estimate the environmental, economic, or social consequences of storage and diversion. Preliminary reports on environmental and other considerations revealed large gaps in knowledge. Reports to the SNBB on possible transfers from the Churchill and Mackenzie River basins suggested that these could have detrimental effects. The Saskatchewan-Nelson Basin Board (1972) stated that:

> "...much more must be known...before decisions are made to build any of these storages or diversions...Perhaps the greatest problem of all will arise when comprehensive planning reveals that the benefits of one alternative for the whole region are greater than any other alternative, while within the boundaries of one

TABLE 16

Effects on minimum flows (m^3/s) of the most successful combination of new projects evaluated by the SNBB (1972)

		Mean Annual Flow[1] (1912 - 67)	Minimum Monthly Flow[1] (1912 - 67)	Suggested Minimum Monthly Flow	Flow for Minimum Month in 1941[2]. (projects operated for uniform flow)		
					With 1970 Uses		With Full Apportionment and new projects[3]
					and existing projects	and new projects[3]	
1	North Saskatchewan River at Edmonton	220	16	n.g.	140	145	145
2	North Saskatchewan River at Alberta-Saskatchewan Boundary	230	16	28	140	350	350
3	Battle River near Forestburg	2.3	0	n.g.	0	3.4	3.4
4	Battle River at Unwin	7.4	<0.1	n.g.	<0.1	11	11
5	Red Deer River at Red Deer	50	2.8	n.g.	2.8	62	62
6	Bow River below confluence with Highwood	130	17	n.g.	42	80	85
7	Oldman River at Lethbridge	115	6.2	n.g.	11	30	30
8	South Saskatchewan River below confluence with Red Deer River	300	24	28	42	205	155
9	South Saskatchewan River at Saskatoon	310	12	42	155	283	57
10	Saskatchewan River below The Forks	565	24	100	270	735	395
11	Saskatchewan River at The Pas	700	32	85	370	920	680
12	Qu'Appelle River outlet of Diefenbaker Lake	0	0	n.g.	0.6	70	70
13	Assiniboine River at Brandon	32	0.1	4.2	10	51	51
14	Souris River at Saskatchewan - N.D. Boundary	2.8	0	ng.	0	4.0	4.0
15	Souris River near Melita	5.4	0	n.g.	0	8.2	8.2
16	Souris River near Wawanesa	7.6	0	n.g.	0	11	11
17	Red River below junction with Assiniboine River	165	3.7	28	22	245	245
18	Nelson River at Warren Landing	1990	325	850	1350	2035	1735

[1] Computed natural flows.

[2] A low fow year.

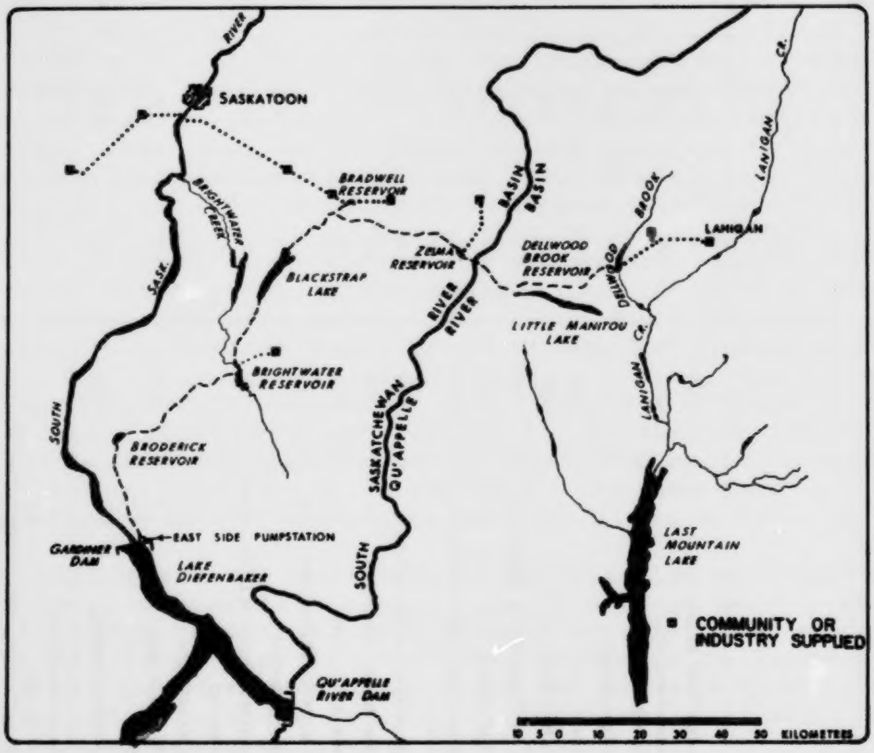
[3] Projects that yielded largest increase in guaranteed flow (includes three large external diversions)

n.g. — not given

> province, another alternative may be greatly preferred. In such situations, a great deal of negotiation will be required to reach a satisfactory compromise".

Over the past decade, some of the interbasin water transfer proposals outlined in the Saskatchewan-Nelson Basin Study have been studied in greater detail, as described in the following.

Figure 19. LOCATION OF TRANSFERS BETWEEN THE SOUTH SASKATCHEWAN AND QU'APPELLE RIVER BASINS (from Dree and Saskatchewan Environment).


RIVER
SASKATOON
BRADWELL RESERVOIR
BRIGHTWATER CREEK
SASK.
BLACKSTRAP LAKE
ZELMA RESERVOIR
BASIN
BASIN
DELLWOOD BROOK RESERVOIR
BROOK
DELLWOOD
LANIGAN
LANIGAN CR.
CR.
RIVER
RIVER
LITTLE MANITOU LAKE
BRIGHTWATER RESERVOIR
SOUTH
SASKATCHEWAN
QU'APPELLE
BRODERICK RESERVOIR
LANIGAN
EAST SIDE PUMPSTATION
GARDINER DAM
LAKE DIEFENBAKER
SOUTH
LAST MOUNTAIN LAKE
■ COMMUNITY OR INDUSTRY SUPPLIED
QU'APPELLE RIVER DAM
10 5 0 10 20 30 40 50 KILOMETRES

Diversions from Lake Diefenbaker to the Qu'Appelle River Basin

In the period from 1958 to 1967, Canada (through the PFRA) and Saskatchewan jointly constructed the Gardiner Dam and the Qu'Appelle River Dam, establishing Lake Diefenbaker on the South

Saskatchewan River (Figure 19). Saskatchewan constructed diversion works to utilize the water of Lake Diefenbaker for irrigation, industrial, recreation, and municipal uses, southeast of Saskatoon; and for use in the Qu'Appelle River basin. Only a small fraction of the flow of the South Saskatchewan (about one percent) is transferred to the Qu'Appelle River.

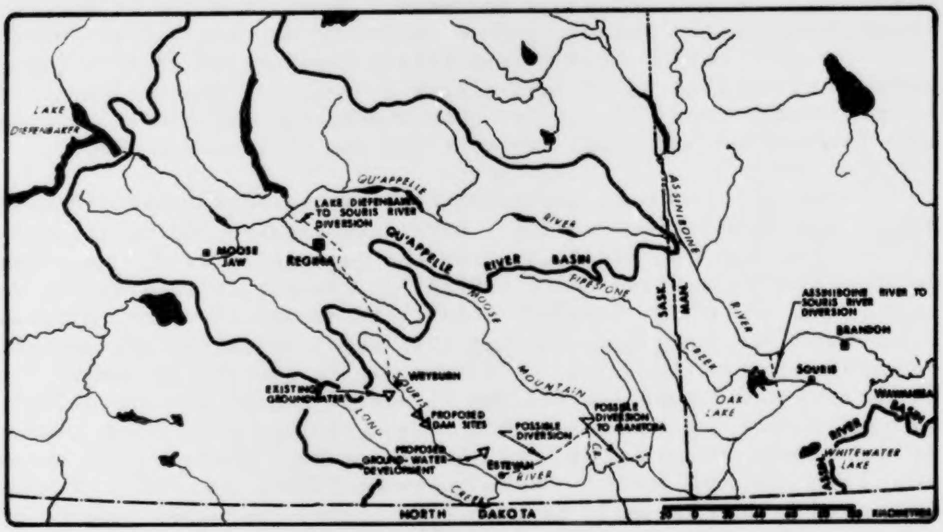
The principal diversion to the Qu'Appelle River is from the Qu'Appelle River Dam at the east arm of Lake Diefenbaker. Water flows by gravity through a man-made channel from the Qu'Appelle River Dam to the upper reaches of the Qu'Appelle River. Though the control works at the dam have a capacity of 74 m^3/s (when Lake Diefenbaker is at full supply level), the channel capacity is presently only 11.3 m^3/s. The average annual diversion from Lake Diefenbaker was about two m^3/s for the period 1977-1980.

Several studies, including that of the Saskatchewan-Nelson Basin Board described earlier, have investigated the possibility of increasing the diversion from the Qu'Appelle River Dam. The Qu'Appelle Basin Study Board (1972) "...thought it inadvisable to increase, without further study, the amount of water imported from Lake Diefenbaker beyond that required to satisfy present demands in the Qu'Appelle River Basin, and future demand for municipal water supplies for the cities of Regina and Moose Jaw". Large water transfers would significantly affect power production, recreation, wildlife, water quality, and water supplies in the South Saskatchewan River Basin, and the Qu'Appelle River would be unable to convey increased amounts of water without flooding valley lands in the absence of additional works (QBSB, 1972).

A second diversion occurs at the East Side Pumpstation near the east end of Gardiner Dam. Called the Saskatoon-Southeast Water Supply (SSEWS) Project, it distributes water via a long system of canals and reservoirs to a variety of users, including local potash industries.

Most of the water is consumed or returns to the South Saskatchewan River, but a small portion is channeled over the divide into the Qu'Appelle River basin. Some of this could flow via Dellwood Brook, Lanigan Creek, and Last Mountain Lake into the Qu'Appelle River. The amount of water transferred, however, is small and does not significantly affect uses in the main body of the Qu'Appelle River basin downstream of Last Mountain Lake.

Figure 20. POSSIBLE DIVERSION FROM LAKE DIEFENBAKER TO THE SOURIS RIVER, VIA THE QU'APPELLE RIVER (SRBSB, 1978).


LAKE DIEFENBAKER
QU'APPELLE
RIVER
LAKE DIEFENBAKER TO SOURIS RIVER DIVERSION
QU'APPELLE RIVER BASIN
MOOSE JAW
REGINA
PIPESTONE
MOOSE
MOUNTAIN
ASSINIBOINE
RIVER
SASK.
MAN.
CREEK
ASSINIBOINE RIVER TO SOURIS RIVER DIVERSION
BRANDON
SOURIS
OAK LAKE
WAWANESA
BASIN
RIVER
WHITEWATER LAKE
WEYBURN
SOURIS
EXISTING GROUNDWATER
LONG
PROPOSED DAM SITES
POSSIBLE DIVERSION
POSSIBLE DIVERSION TO MANITOBA
PROPOSED GROUND-WATER DEVELOPMENT
ESTEVAN
RIVER
CREEK
NORTH DAKOTA
KILOMETRES

Water Supply for the Souris River Basin

The Souris River Basin Study (SRBSB, 1978) by the governments of Canada, Manitoba, and Saskatchewan was intended to formulate a plan for managing the water and related resources of the Canadian portion of that basin. The Souris River Basin Study Board (SRBSB) examined problems associated with flooding, inadequate water supplies, and variations in water quality. Interbasin transfers were considered as possibilities for increasing supply (Figure 20). The Souris River basin, as presently developed, does not have sufficient water supply to meet demands in dry years, particularly at Weyburn and Boundary Reservoir.

Among the water supply possibilities evaluated were: open channel and pipeline diversions from Lake Diefenbaker via the Qu'Appelle River to the Souris River, and an open channel diversion from the Assiniboine River to the Souris River. For Saskatchewan, it was concluded that enlargement of Weyburn Reservoir and the development of ground water in the Estevan Valley Aquifer would meet the foreseeable future water demand. Only if a large industrial demand for water arose would water need to be imported from Lake Diefenbaker. Diversions to improve the water supply in Manitoba were judged by the SRBSB to be uneconomical or more expensive than other alternatives.

A further review of water demand and supply alternatives in this region is being undertaken under federal-provincial agreements on water development, (Canada-Saskatchewan, 1979; Canada-Manitoba, 1980). However, there are no present indications that interbasin transfer solutions are contemplated.

Southern Alberta Irrigation Projects

Irrigation is more widespread in southern Alberta than in any other part of the Study Region. Water is diverted from streams in the Oldman River and Bow River basins and distributed by canal to nearly 900,000 acres (360 000 ha) of farmland. A detailed account of diversions in these projects is found in Chapter VIII.2. The major portion of this water is consumed through evapotranspiration from croplands and is lost locally to the atmosphere. A smaller fraction returns to streams via drainage ditches and tributaries.s. In some cases, the return flow is to other drainage basins. In this way, transfers take place between the Bow River and the Oldman and Red Deer River basins (Table 17).

TABLE 17. VOLUMES OF WATER TRANSFERRED DUE TO IRRIGATION IN SOUTHERN ALBERTA (DAM^3) (ENVIRONMENT CANADA, 1978D, 1979A, 1980C)

	1977	1978	1979
BOW R. TO RED DEER R.	110 000	121 000	136 000
BOW R. TO OLDMAN R.	33 000	20 000	25 000

In the southwest corner of Alberta, the Waterton, Belly, and St. Mary Rivers enter Canada from Montana. Proposals by both Canada and the United States to divert water from these streams in the early 1900s gave rise to international concerns and led, in part, to the formation of the International Joint Commission in 1909 and the International Boundary Waters Treaty. In 1917, a diversion of 9.4 m^3/s was developed from the St. Mary River to the Milk River, in Montana, but it was not until 1921 that agreement on apportionment was reached through the IJC (Chapter I.7).

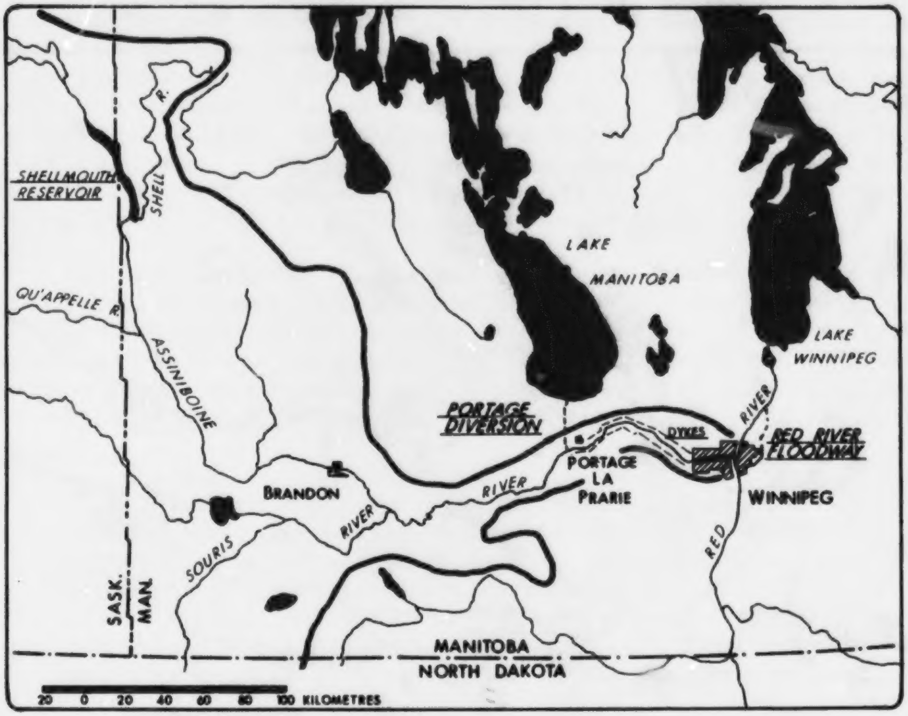
It has been estimated that irrigation demand in southern Alberta could expand in the future to such an extent that additional water would be needed in this region (UMA, 1980). The possibility of importation of water from basins lying to the north of the Oldman and Bow River basins was put forth in the late 1960s by the Alberta government in its Prairie Rivers Improvement, Management, and Evaluation (PRIME) program. As demand approached supply, water was to be transferred first from the Red Deer River, then the North Saskatchewan River, and eventually the Peace and Athabasca Rivers. The projects suggested were similar to those described by the Saskatchewan-Nelson Basin Board. However, the idea of interbasin transfer of this scope was given a low priority by the government elected in 1971.

More recently an Advisory Committee on Water (ACW) has been reviewing these and other possibilities within the context requirements of the province. By late 1981, the ACW had not produced any public recommendations.

The Portage Diversion

The Portage Diversion in Manitoba (Figure 21) was constructed to reduce the impact of flooding on agricultural and urban lands, including the city of Winnipeg. It is a component of a larger system of flood control in the mildly sloping Red River and Assiniboine River valleys, which includes the Shellmouth Reservoir on the Assiniboine River, dyking systems built along both sides of the Red and Assiniboine Rivers, and the Red River Floodway. The land near to the lower Assiniboine River actually slopes away from the river, making it difficult for water to drain back into the river following a flood crest.

Figure 21. LOCATION OF THE PORTAGE DIVERSION BETWEEN THE ASSINIBOINE RIVER AND LAKE MANITOBA (DREM, 1974).


SHELLMOUTH RESERVOIR
SHELL R.
QU'APPELLE R.
ASSINIBOINE
LAKE MANITOBA
LAKE WINNIPEG
PORTAGE DIVERSION
DYKES
RIVER
RED RIVER FLOODWAY
PORTAGE LA PRARIE
WINNIPEG
BRANDON
RIVER
RIVER
SOURIS
RED
SASK.
MAN.
MANITOBA
NORTH DAKOTA
20 0 20 40 60 80 100 KILOMETRES

Completed in 1970, the diversion permits the discharge of up to 700 m^3/s of flood waters from the Assiniboine River, just upstream of Portage la Prairie, to Lake Manitoba. Drop structures along the diversion channel slow the water and thereby reduce erosion.

Assiniboine River Basin - Red River Basin Diversion

The Canada-Manitoba Agreement (1980) referred to earlier includes evaluations of the possible benefits of diverting waters from the Assiniboine River near Portage la Prairie southward. A number of alternatives, which have been described by the SNBB (1972), could result in increased supplies for irrigation almost as far south as the North Dakota boundary. The return flows from these possible diversions would flow to the Red River.

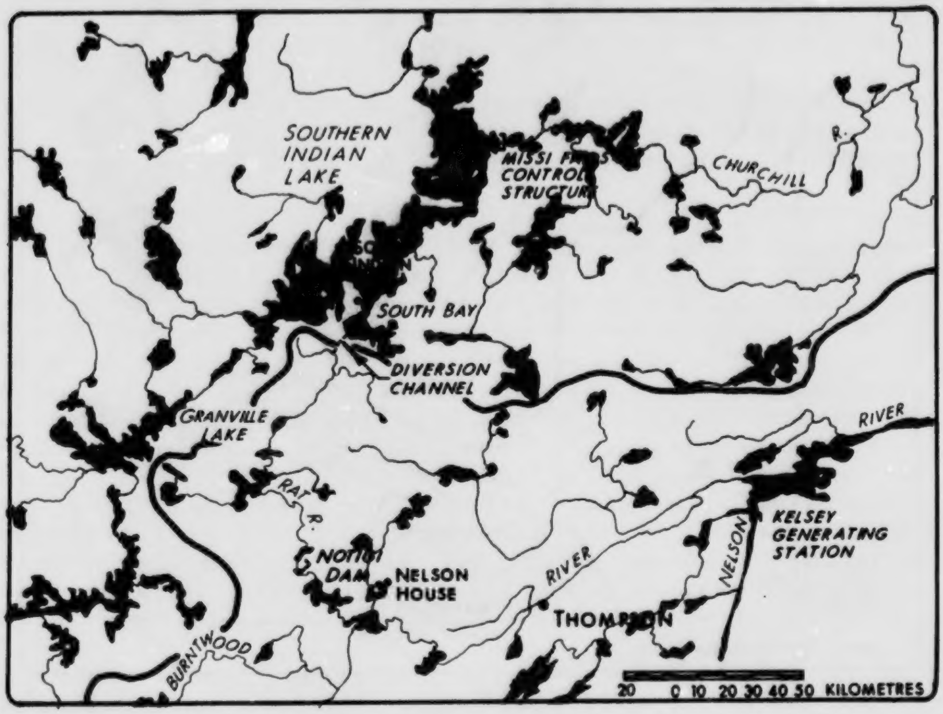


Figure 22. LOCATION OF THE DIVERSION BETWEEN THE CHURCHILL AND NELSON RIVERS (after: Guilbault Et Al, 1979).

SOUTHERN INDIAN LAKE
MISSI FALLS CONTROL STRUCTURE
CHURCHILL
R.
SOUTH BAY
DIVERSION CHANNEL
GRANVILLE LAKE
RAT R.
RIVER
KELSEY GENERATING STATION
NELSON
NOTIGI DAM
NELSON HOUSE
RIVER
THOMPSON
BURNTWOOD
20 0 10 20 30 40 50 KILOMETRES

The Churchill Diversion

The transfer of water from the Churchill River to the Nelson River (Figure 22) is the largest interbasin water transfer in the Study Region and is a part of the Churchill- Nelson Hydroelectric Development Scheme operated by Manitoba Hydro.

In 1966, the Manitoba government decided to develop the Nelson River for hydro-electric power and to divert a large portion of the Churchill River into the Nelson River, rather than develop each separately. Manitoba Hydro proposed a high volume diversion at Southern Indian Lake, an initial 1020 megawatt generating station at Kettle Rapids, an extra-high-voltage, direct-current transmission line from Kettle Rapids to Winnipeg, and works to regulate outflow from Lake Winnipeg. Environmentalists and native people of northern Manitoba voiced opposition to the diversion, mainly on the grounds that it would severely disrupt fishing and trapping in the Southern Indian Lake region and would force the entire community of South Indian Lake to move to higher ground. After further studies and public hearings, a provincial task force proposed a new plan which combined regulation of Lake Winnipeg with a smaller-volume diversion. The plan was accepted by the Province in 1970.

The governments of Canada and Manitoba initiated the Lake Winnipeg, Churchill and Nelson Rivers Study in 1971, which was undertaken concurrently with the construction of the Manitoba Hydro projects..."recognizing the overall interest and conflicts over the use of the water and related resources" (Lake Winnipeg, Churchill, and Nelson Rivers Study Board, 1975). The objective was:

> "...to determine the effects that the regulation of Lake Winnipeg, diversion from the Churchill River and development of hydro-electric potential of the Churchill River diversion route are likely to have on other water and related resource uses and to make recommendations for enhancing the overall benefits with due consideration for protection of the environment".

Among the more important implications for northern Manitoba, the Study Board projected:

- increased employment until 1990,
- improved transportation facilities,
- increased tourism,
- a 10 percent reduction in fish productivity in Southern Indian Lake,
- cessation of commercial fishing on the lower Churchill River,
- reduction of the wild fur industry (perhaps permanently in the lower Churchill River),
- no significant mining and forestry effects,
- social stress, cultural breakdown, and nutritional and health problems for northern people, and
- water supply problems for the townsite of Churchill.

The Board made a total of 47 recommendations, including a general proposal for a body to advise on the management of the waters affected by the scheme, specific recommendations such as that fish populations be monitored, and a recommendation that all-weather access roads be constructed.

The diversion works were completed in 1976. They included the Missi Falls control structure on the Churchill River at the outlet of Southern Indian Lake and a channel joining Southern Indian Lake to the Rat River (a tributary of the Burntwood River which flows into the Nelson River at Split Lake). A control structure at Notigi on the Rat River regulates the rate of flow diverted into the Nelson River. The provincial license permits an average flow of 850 m^3/s to be discharged at Notigi, whereas the original proposal called for a diversion of 1400 m^3/s. The license also stipulates that the outflow from the control dam at Missi Falls must be at least 14 m^3/s during the open water season and 43 m^3/s during the ice cover period.

Southern Indian Lake has been raised about 3 metres (as compared to 10 m in the first proposal), flooding about 520 km^2 of land around the lake. Another 410 km^2 may be flooded along the diversion route (including 8 km^2 of the Nelson House Indian Reserve). It is estimated that the mean annual discharge of the Churchill River at the outlet of Southern Indian Lake will drop to less than 25 percent of its historical average, and that the discharge of the Burntwood River at Thompson will be over nine times its pre-diversion average (Guilbault, Gunner, and Chacko, 1979).

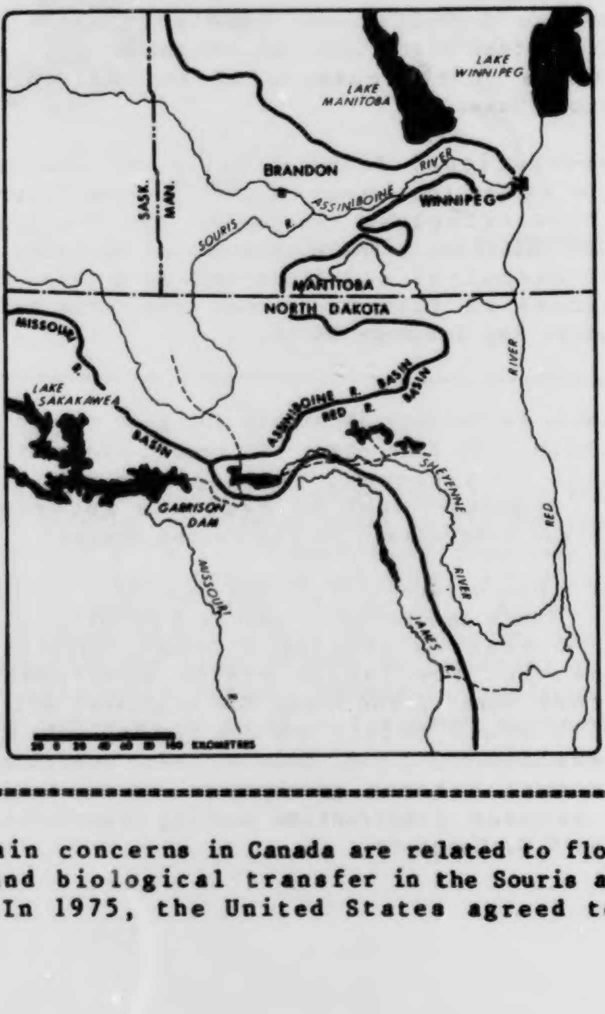
The Garrison Diversion Unit

The Garrison Diversion Unit (Figure 23) is a United States project designed to enhance irrigation, municipal, and industrial water supplies; and to facilitate fish and wildlife management, in North Dakota. Nearly one billion cubic metres per year could eventually be transferred from the Missouri River into the Hudson Bay drainage basin. Return flows from irrigation and most of the water diverted for other uses would enter Canada via the Souris and Red Rivers. The transboundary implications of the project are significant and considerable controversy has developed around it.

The Garrison Dam on the Missouri River was completed in 1956 as part of the Pick-Sloan Missouri Basin Program, a huge multi-purpose water development program. In 1965, the United States Congress approved the Garrison Diversion Unit.

Construction was started in 1967, but only about one quarter of the work has been completed. So far, no water has yet crossed the continental divide. Opponents of the project in both the United States and Canada have forced postponements and modification of the original plans. The National Audubon Society established the project as one of its top "action priorities", and caused it to be suspended in 1981. The U.S. Environmental Protection Agency has objected to the project on environmental grounds.

Figure 23. LOCATION OF THE GARRISON DIVERSION UNIT.


LAKE WINNIPEG
LAKE MANITOBA
BRANDON
RIVER
ASSINIBOINE
WINNIPEG
SASK.
MAN.
SOURIS
R.
MANITOBA
NORTH DAKOTA
MISSOURI
R.
LAKE SAKAKAWEA
BASIN
ASSINIBOINE R. BASIN
RED R. BASIN
RIVER
SHEYENNE
RIVER
GARRISON DAM
MISSOURI
R.
RED
JAMES R.
20 0 20 40 60 80 100 KILOMETRES

The main concerns in Canada are related to flooding, water quality, and biological transfer in the Souris and Red River basins. In 1975, the United States agreed to halt all construction affecting Canada until the situation was reviewed by the International Joint Commission. Findings were published in 1977 and substantiated some of the fears raised earlier:

- the mean annual flow on the Souris River would increase 48 percent, although increased flooding would not be extensive in Canada.

- the water quality of the Souris River would be significantly changed (primarily by increased nutrient and salt concentrations in return flows from irrigation) creating additional water treatment costs for industrial users and municipalities.

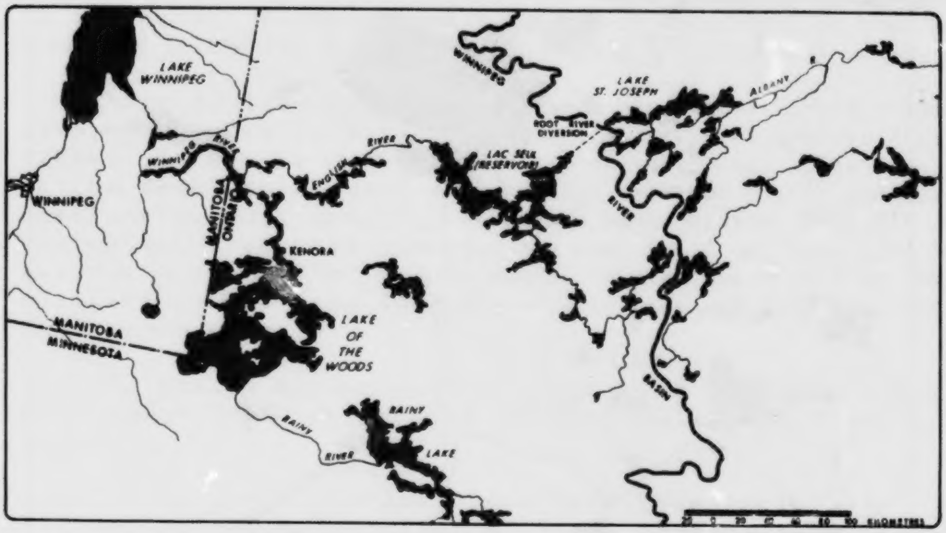
- there is insufficient knowledge as to the effect of foreign fish migrations and the transfer of parasites and bacteria on the commercial and sports fisheries in Manitoba lakes.

The International Joint Commission made several recommendations to reduce the impact of the Garrison Diversion Unit in Canada, but nevertheless recommended that the transfer not be permitted at that time. The government of Manitoba has rejected any form of technical solutions such as screens to filter out foreign species of fish and other life forms before they can enter the Hudson Bay drainage basin.

> "Available technology is simply not good enough to stop every fish. Or fish eggs. It cannot stop water-borne parasites or diseases. It can't be made accident-proof" (Brochure sent by Manitoba government to senators and congressmen in the United States).

The Garrison Diversion Unit has reached a critical stage of development. Funds amounting to nearly four million dollars have been put in reserve pending further Canadian-American negotiations, but the United States government has given assurance that none of the money now allocated will be spent in any way which would affect waters flowing into Canada. In a mid-1981 development, a U.S. federal court sustained an earlier (1977) agreement between governments and the National Aubudon Society to suspend construction pending reauthorization of the project by the U.S. Congress.

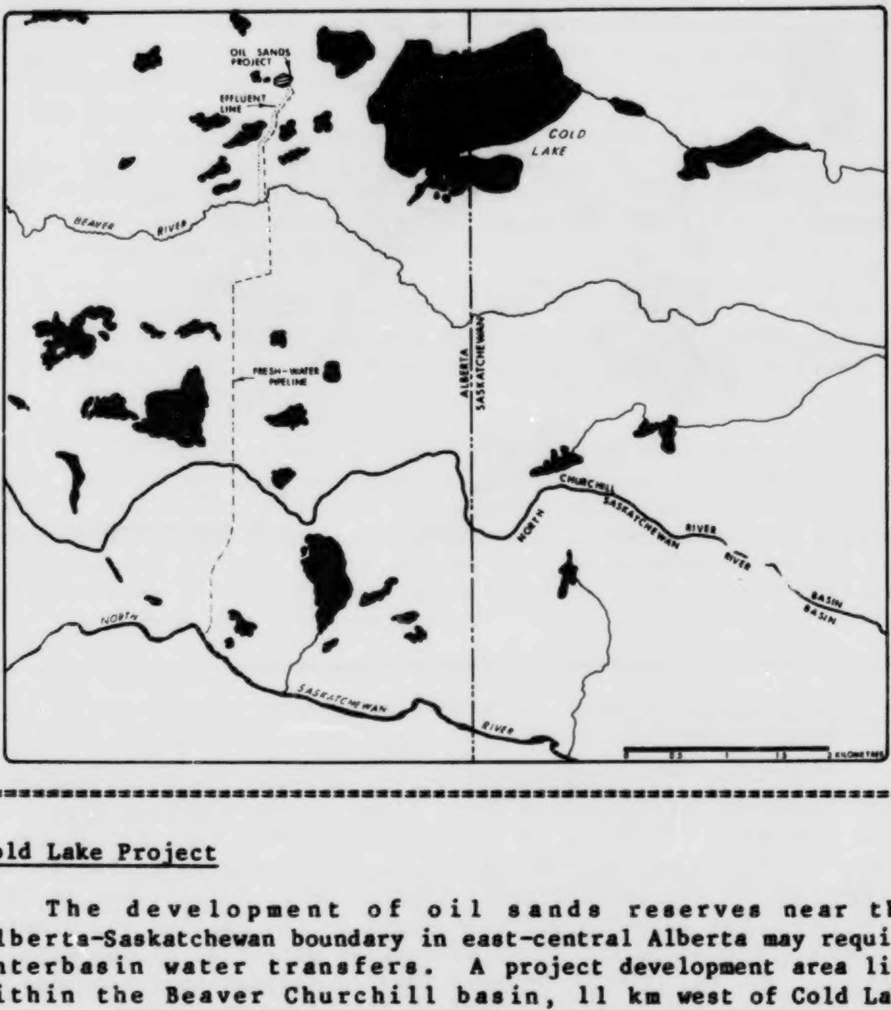
Figure 24. LOCATION OF THE ROOT RIVER DIVERSION (SNBB, 1972).


LAKE WINNIPEG
WINNIPEG
LAKE ST. JOSEPH
ALBANY
ROOT RIVER DIVERSION
WINNIPEG RIVER
ENGLISH RIVER
LAC SEUL (RESERVOIR)
RIVER
WINNIPEG
MANITOBA
ONTARIO
KENORA
LAKE OF THE WOODS
MANITOBA
MINNESOTA
RAINY RIVER
RAINY LAKE
BASIN
20 0 20 40 60 80 100 KILOMETRES

Root River Diversion

The Root River Diversion occurs outside the Study Region in northwestern Ontario but affects flows in the Winnipeg River. On the average, 75 m^3/s is transferred from Lake St. Joseph in Ontario (in the headwaters of the Albany River) to Lac Seul, a widening of the English River (Figure 24). Established in 1957, the transfer augments off-peak flows on the English and Winnipeg Rivers, increasing the power production potential of the Winnipeg River. An agreement between Ontario and Manitoba provides for sharing costs and benefits based on the power produced.

Figure 25. LOCATION OF A PROPOSED PIPELINE FOR TRANSFER OF WATER FROM THE NORTH SASKATCHEWAN RIVER TO THE COLD LAKE AREA (Esso Resources Canada Ltd., 1979).


OIL SANDS PROJECT
EFFLUENT LINE
COLD LAKE
BEAVER RIVER
FRESH-WATER PIPELINE
ALBERTA
SASKATCHEWAN
CHURCHILL
NORTH
SASKATCHEWAN
RIVER
RIVER
BASIN
BASIN
NORTH
SASKATCHEWAN
RIVER

Cold Lake Project

The development of oil sands reserves near the Alberta-Saskatchewan boundary in east-central Alberta may require interbasin water transfers. A project development area lies within the Beaver Churchill basin, 11 km west of Cold Lake (Figure 25). The purpose of the project is to recover and upgrade crude bitumen from the Cold Lake Oil Sands deposit, using an *in situ* steam stimulation process.

Fresh water make-up for the project may amount to just over one m^3/s. Recycling will provide another 0.6 m^3/s. Nearly one-half of the total will be required for steam injection with a large fraction consumed in displacing the bitumen. The balance will be used mainly in hydrogen synthesis, for cooling, and as process water and steam. There will be significant losses to evaporation, and treated waste waters will likely be discharged to the Beaver River. Remaining waste water will be high in dissolved solids and will be discharged via deep disposal wells.

Three sources of fresh water have been investigated - Cold Lake, the North Saskatchewan River, and several smaller local lakes. Cold Lake is the less costly source, since it is closer to the development area and provides water of higher and more constant quality. A control structure would have to be built on the outlet from Cold Lake, but its cost would be outweighed by savings in pipeline and pumping costs. A pipeline from Cold Lake would result in less land disturbance than one from the North Saskatchewan River.

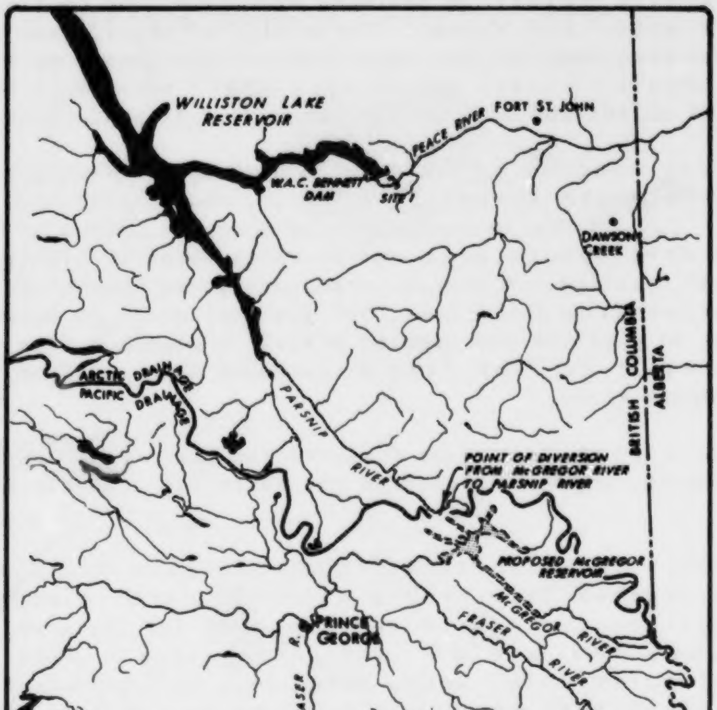
The Energy Resources Conservation Board (ERCB) and Alberta Environment, however, preferred the North Saskatchewan River as a source:

> "Since the withdrawal from Cold Lake would have unforeseen deleterious effects, particularly if additional projects were approved for the area, and since the use of Cold Lake raises a need for interprovincial water management, the Board does not believe that the use of Cold Lake as a make-up source would be appropriate" (ERCB, 1979).

This solution would result in an interbasin transfer of water.

Intervenors at the hearings expressed concern that industrial use of the lake would be detrimental to established recreation, fisheries, and environmental values. Saskatchewan Environment was concerned about the lack of information for evaluating the effects of the project in Saskatchewan. Subsequently, the proponent has examined other local sources, such as the smaller lakes, as a third alternative.

Figure 26. LOCATION OF PROPOSED McGREGOR DIVERSION (Reid, Crowther, and Partners, 1978).


WILLISTON LAKE RESERVOIR
PEACE RIVER
FORT ST. JOHN
W.A.C. BENNETT DAM
SITE I
DAWSON CREEK
BRITISH COLUMBIA
ALBERTA
ARCTIC DRAINAGE
PACIFIC DRAINAGE
PARSNIP RIVER
POINT OF DIVERSION FROM McGREGOR RIVER TO PARSNIP RIVER
PROPOSED McGREGOR RESERVOIR
McGREGOR RIVER
FRASER RIVER
PRINCE GEORGE
FRASER R.
20 0 20 40 60 80 100 KILOMETRES

McGregor River Diversion

In 1978, British Columbia Hydro suspended engineering and environmental studies of a proposed diversion from the McGregor River to the Peace River. The proposal was to dam the McGregor River (a tributary of the Fraser River) to form a reservoir which would overtop the Arctic/Pacific divide at the head of James Creek (Figure 26). The outflow from the reservoir would have significantly increased flows in the Parsnip River (by almost ten-fold below Arctic Lake and two-fold near the river's mouth at Williston Lake) and reduced flow in the McGregor and Fraser Rivers below the dam. The development would have increased the average annual energy production at hydro plants along the Peace River and provided flood control benefits along the Fraser River. The diversion would have transferred up to 200 m^3/s during a flood stage (Reid, Crowther and Partners Ltd., 1978).

Information from environmental studies prompted suspension of the project, according to B.C. Hydro (1978). The main concern related to fish parasites which are not common to both the Arctic drainage and the Pacific drainage. While fish movement from the Arctic to the Pacific could be prevented, it would not be feasible to prevent fish, and therefore parasite, movement from the Pacific to the Arctic. Five parasites that have been known to cause mortalities in fish were found in the Pacific drainage and not the Arctic. Many other negative impacts on fisheries, wildlife habitat, forestry, water quality, and recreation were also identified, though some mitigation was possible.

Continental Water Transfer Proposals

During the mid-1960s, a number of continental diversion schemes received public attention. For the most part, they were devised by consulting engineers and academics, and described only the engineering works and technology required. Economic analyses were tenuous and there was little or no reference to environmental or social impacts. The key objective of the proposed projects was to transfer apparently surplus Arctic-flowing waters southward for use in the arid and semi-arid regions of western Canada, the United States, and northern Mexico. Vast quantities of water were to be conveyed over very long distances using canals, pipelines, tunnels, and pumps. The Study Region of this report was involved in at least five of these continental schemes.

For historical purposes, these proposals are described below. However, it is important to note that no federal or provincial government has ever seriously considered any of them.

The North American Water and Power Alliance (NAWAPA), was proposed in 1964 and is still promoted by the Ralph M. Parsons Company of Los Angeles. This plan involves the transfer of over 120 million dam^3 of water from Alaska, the Yukon, and British Columbia to water-deficient areas of Canada, the southwestern

United States, and northern Mexico. NAWAPA also proposed a navigable waterway across the prairie provinces, connecting the Fraser River with the Great Lakes and Hudson Bay. The cornerstone of the plan is a 800 km-long storage reservoir in the Rocky Mountain Trench of interior British Columbia. This would flood several thousand acres of arable land, mineral and forest leases, and several communities, and would interrupt a number of transportation routes. Over 175 lakes and reservoirs, thousands of kilometres of canals, and hundreds of irrigation systems would be created at an estimated cost of over 200 billion (1977) dollars.

On a slightly smaller scale, the Western States Water Augmentation Concept, proposed by Smith (1969), would reverse the flow of the Liard River, and a portion of the flow of the Mackenzie River near the mouth of the Liard. Water could then be lifted into the Rocky Mountain Trench and delivered to the United States. An addition to the proposal involved redistribution of waters in the Peace, Athabasca, and Saskatchewan-Nelson River basins using projects not unlike those investigated by the Saskatchewan-Nelson Basin Board.

Tinney (1967) developed the Central North America Water Project (CeNAWP) scheme to transfer the waters of the Mackenzie, Churchill, and Nelson River basins, using many natural lakes as reservoirs, from Great Bear Lake to Winnipeg, then south to central and southwestern United States and northern Mexico. No benefits, other than revenue from the sale of water, would accrue to western Canada, but Tinney claimed that CeNAWP would create fewer effects on the natural environment than the other large continental schemes proposed.

Kuiper (1961) speculated that in the far future many more people might live in the prairie provinces and that much more food might have to be produced. The water required for these purposes could physically be diverted from the Athabasca River, the Churchill River, and Lake Winnipeg. Water would be pumped up through a series of dams and reservoirs on the Saskatchewan River system and be distributed through a network of canals.

Kuiper (1966) pointed out that if diversions from the Peace River are included, the total available water supplies of the three prairie provinces may exceed their water requirements in the foreseeable future by as much as one million dam^3 per year.

He concluded (Kuiper, 1968) that export of Canadian water to the United States, although physically possible, would in the foreseeable future be economically unattractive. The cost of transfer to the international boundary plus the resource value that Canada would demand, plus the cost of transfer to the United States destinations would far exceed the intrinsic value of that water.

Magnusson (1969) described the 'Magnum Diversion' for export of water from prairie and northern rivers. Designed in phases, starting with diversion from the South Saskatchewan River to the Souris River entering the United States, it would eventually draw from the Liard River (and possibly even the Yukon River). As well as serving local irrigation projects and industrial developments, the canal could also be used for shipping.

These schemes are not being considered by either the federal or provincial governments. There is a general rejection of the idea that Canadian waters should be regarded as a continental resource (Clark, Rosenburg, and Quinn, 1978). Nor has the government of the United States made any offers to the Governments of Canada or promoted discussion of any of the private schemes. Their value and inadequacies are clearly summed up by Tinney and Quinn (1969):

> "To the extent that they have collectively focused public attention on water problems and opportunities and have provoked debate on our goals and constraints, we must applaud these contributions. But none of them tell us all we need to know. These are engineering schemes, privately sponsored; whether they speak to human needs and public goals; whether they provide the most efficient system for economic growth, allow for its equitable distribution interregionally and internationally, and protect environmental qualities for other kinds of human fulfillment, remains unknown. And to the extent that some of these continental thinkers promote their schemes as panaceas, insensitive to other public needs and political sovereignties, they clearly hurt their own cause."

Consideration of continental water transfers is premature even today, and this has been reflected in the lack of further discussion since the 1960s.

3. DROUGHT, FLOODING, AND DRAINAGE

Human activities have done much to influence the temporal and spatial distributions of water in the Study Region, but natural processes still are paramount in governing these distributions. The hydrologic cycle fundamentally influences the dimensions of surface streams, lakes, and wetlands; and the nature of flora and fauna in any specific drainage region. The variability of components of the hydrologic cycle is correspondingly influential on changes in these natural phenomena.

Drought

Periods of reduced precipitation in a drainage region can result in drought. If the surface drainage systems (rivers, lakes) experience substantial water reductions, this could be termed a "runoff drought". If the lands adjacent to the drainage system become significantly moisture-deficient, this is termed an "agricultural drought". Thus, a very dry spring season, following a winter that featured substantial snow storage upstream, could result in near normal river flows in a region of agricultural drought. Conversely, normal or above normal spring precipitation, following a dry period with low winter snow storage, might produce a runoff drought amidst flourishing vegetation. A recent discussion of definitions of "drought" and its characteristics is presented by Chin (1978).

Prolonged dry periods inevitably result in widespread drought of both types. McKerness (1979) indicates that at least 20 serious droughts occurred in western Canada during the 19th century. She suggests a similar frequency of occurrence up to the 1940s, with the drought of the 1930s being "the most memorable". Most recently, the 1976/77 drought, though short-lived, was widespread and severe in the Interior Plains.

Droughts can have major repercussions in all water use sectors. Though agriculture is commonly considered to be most vulnerable, the effects of increased forest fires, diminished power generation, reduced waterfowl habitat, curtailed water supplies for municipal and industrial uses, and damages to the environment can be extensive. In the case of the 1976/77 drought, the greatest economic impact was not to agriculture, though that was substantial, but to the loss of energy production. Replacement energy costs were estimated at $100 million (Bruce, 1979).

Agriculture, however, has faced the reality of drought for many decades in the Study Region. Dryland farming is highly susceptible to the effects of agricultural drought, while irrigation farming is affected to a lesser degree by either agricultural or runoff droughts, or both. Because even the "normal" climate of this region is arid or semi-arid, farmers and ranchers can expect to experience periodic dry periods of varying severity. For the dryland farmer, crop selection and rotation, and practices related to tillage and harvesting, are important for soil moisture conservation. For the rancher, careful range management practices are necessary. For the irrigation districts and individual irrigators, there are the additional requirements for efficient storage and conveyance of waters to the point of use, and efficient application to crops.

As a result of the conditions of the 1930s, the federal government, through the Prairie Farm Rehabilitation Administration (PFRA), began a program that undertook or subsidized numerous projects for the enhancement and protection of water supplies for agriculture. In recent years, Alberta, Saskatchewan, and Manitoba have also committed large resources for this purpose. For example, Alberta recently allocated $334 million for the improvement of storage and supply works in the southern part of the province (Alberta Environment and Alberta Agriculture).

In 1979, the federal government, through the Department of Regional Economic Expansion, entered into an agreement with Saskatchewan for joint funding of $13.2 million for programs to reduce the economic impact of future drought situations. A similar agreement between Manitoba and the federal government ($8.95 million) was signed in 1980.

In more northerly portions of the Study Region, climatic conditions in many years are favourable for agriculture, but aridity is often a constraining factor. In the Slave River lowlands, this factor is as important as growing season temperatures and frost-free period length (Findlay, 1981).

Flooding

Flooding occurs when there is an excess of water. In mountain and foothills portions of the Study Region, flooding can result from rapid snowmelt, heavy periods of rainfall, or ice jamming during spring breakup. In the Interior Plains, rainfall has to be extreme over large areas to cause flooding, so that snowmelt and ice jams are usually the major factors. Rainfall can cause local flooding in urban areas where storm sewer or open drain capacities are inadequate to handle the increased runoff caused by urbanization.

The failure of water control structures (dams, dykes) can potentially result in catastrophic flooding. Although this is a rare occurrence, and there are no instances of major dam failures in this part of Canada, small structures have failed, causing local flooding. The breaching of the St. Mary Project main irrigation canal in southern Alberta in 1974 resulted in $250,000 in damage claims (Alberta Environment).

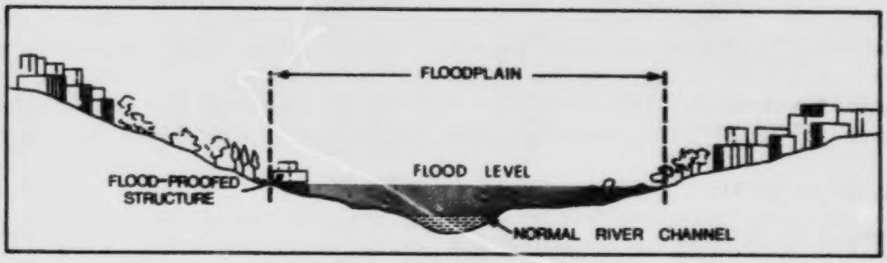
The magnitude and frequency of natural floods can be difficult to forecast, but areas susceptible to effects are usually identifiable. Where flooding is undesirable, action can be taken to either prevent or restrict flooding, to reduce the potential for damage, or to compensate for damages. Each of these measures can be very expensive, though preventive measures have been shown to be cost-effective. In many cases, it is more desirable to restrict flood-susceptible development in areas that are flood-prone.

Flooding is a valuable natural event in some instances. The major river systems in the Study Region each form delta structures upon entering major lakes or marine bodies (Red, Saskatchewan, Peace-Athabasca, Slave, and Mackenzie River deltas). The deposition of materials during flood stage is essential to the ecology of these areas. Fish habitat in many rivers is enhanced by periodic flooding. Floodplain fertility may be improved by periodic flooding, although this benefit can be in conflict with the desire for improved reliability of agricultural use. Farmers have also made constructive use of spring floods for irrigation purposes.

A schematic illustration of a river floodplain is contained in Figure 27. The floodplain is a relatively level zone adjacent to a river which becomes inundated when the river overflows its banks. A 100-year floodplain is the largest area that can, on average, be expected to be flooded once in every 100 years. (Note, however, that the proper statistical definition is that in each and every year there is a one in 100 chance of the area being flooded.)

Flood problems continue to exist throughout the Study Region in wet years, despite considerable government expenditures on flood forecasting, preventive structures, and efforts to constrain development in floodplains. The Red River Floodway, the Portage Diversion, and the Shellmouth Dam, which cost $100 million, are credited with preventing an estimated $200 million in damages in 1974 alone, by controlling flows in the Assiniboine River and diverting water from the Red River around the City of Winnipeg. Other examples are described later in sections dealing with specific basins. Fitzgibbon (1981) provides comment on flooding in each drainage basin.

Figure 27. ILLUSTRATION OF FLOODPLAIN FEATURES (after Environment Canada, 1978e).



In 1975, a national Flood Damage Reduction Program was implemented by the federal government, the Northwest Territories, and some provinces to identify flood-prone areas and discourage development in them. Flood-risk maps are prepared to aid in local planning. By mid-1981, agreements within this program had been reached for work at Winnipeg, Melita, Wawanesa, Souris and other locations in Manitoba; 30 locations in Saskatchewan; and Hay River in the Northwest Territories. Federal-provincial agreements have not been signed with Alberta and British Columbia.

Alberta Environment has a floodplain delineation program involving several locations including the Elbow River in Calgary. The British Columbia Ministry of Environment also has a floodplain development control program, although this deals primarily with locations outside the Study Region.

TABLE 18. GROSS AND EFFECTIVE DRAINAGE AREAS TRIBUTARY TO HYDROMETRIC STATION IN THE PRAIRIE PROVINCES (DREE, 1978B)

NAME OF STATION	DISTANCE FROM MOUTH (KM)	EFFECTIVE DRAINAGE AREA (KM²)	GROSS DRAINAGE AREA (KM²)	PERCENT EFFECTIVE
OLDMAN R – NEAR LETHBRIDGE	155.1	15 760	17 000	92.6
– NEAR MOUTH	11.0	21 310	27 510	77.5
BOW R – NEAR BASSANO DAM	170.0	18 120	20 270	89.4
– NEAR MOUTH	19.4	19 520	25 290	77.2
RED DEER R – NEAR BINDLOSS	47.9	31 620	44 680	70.8
– NEAR EMPRESS	20.0	32 410	46 790	69.3
N. SASK R – NEAR EDMONTON	831.1	27 340	28 010	97.6
– NEAR DEER CR.	456.9	42 700	57 090	74.8
– AT PRINCE ALBERT	62.0	72 250	131 400	55.0
BATTLE R – NEAR UNWIN	209.2	11 170	25 910	43.1
– NEAR MOUTH	8.1	13 620	30 000	45.4
S. SASK. R – AT HIGHWAY 41	733.9	46 640	65 970	70.7
– NEAR LEMSFORD	628.3	80 100	119 400	67.1
– AT ST. LOUIS	97.5	88 140	148 250	59.5
SASK. R – AT THE PAS	216.1	223 040	347 210	64.2
QU'APPELLE R – NEAR WELBY	40.6	16 970	50 850	33.4
ASSINIBOINE R – AT KAMSACK	1011.4	4 320	12 950	33.4
– AT HEADINGLY	25.9	57 270	153 180	37.4
SOURIS R – NEAR SHERWOOD	830.0	6 500	22 350	29.1
– AT WAWANESA	21.1	19 550	60 280	32.4
EAGLE CR. – NEAR ENVIRON	22.1	2 090	11 850	17.6
BEAVER R – AT COLD L. RESERVE	440.9	11 600	14 530	79.9
– BELOW WATERHEN R	88.1	38 600	44 980	85.8
CARROT R – NEAR SMOKY BURN	215.6	7 020	9 240	76.0
CHURCHILL R – AT SANDY BAY		203 110	209 570	96.9
– BELOW FIDLER L.		262 610	269 080	97.6
CLEARWATER R – NEAR ROCKY MTN HOUSE		3 210	3 220	99.7
SMOKY R – AT WATINO		49 570	50 250	98.6
ATHABASCA R – AT ATHABASCA		73 280	74 620	98.2

NOTE: BASED ON REVISIONS TO PFRA (1978B) TABULATIONS AS UPDATED TO NOVEMBER 3, 1981.

Drainage

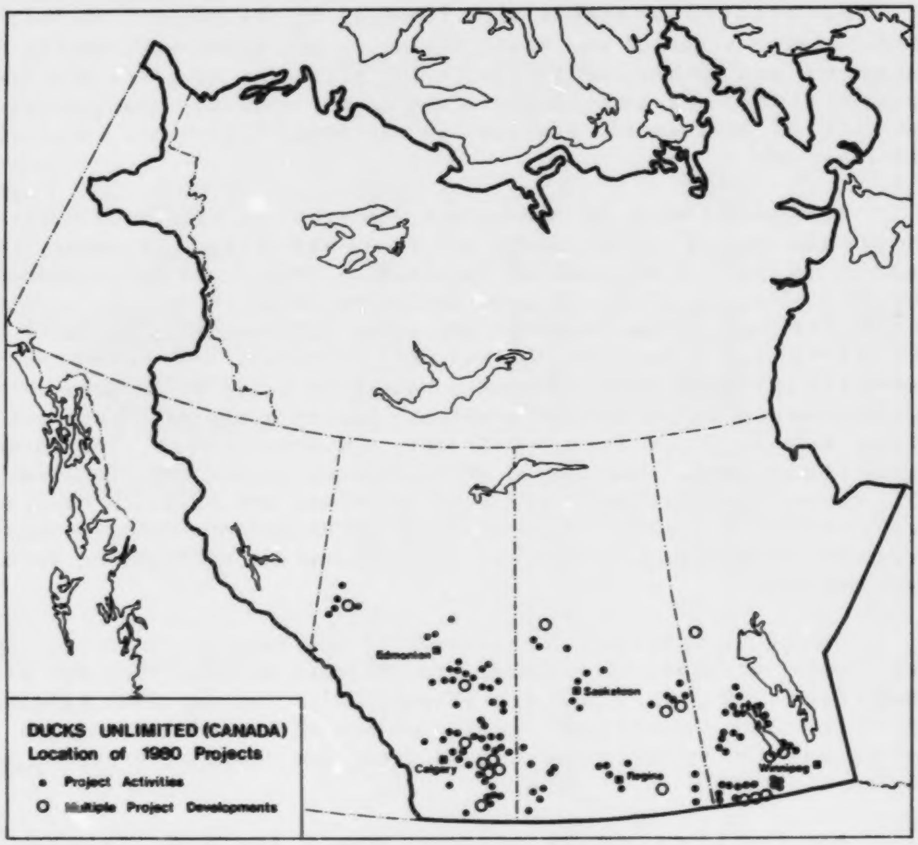
Associated somewhat with flooding is the subject of drainage. Large areas of the Study Region do not drain efficiently to streams and lakes, or to aquifers. Estimates of gross drainage areas and areas that are drained on the average, upstream of a number of hydrometric stations in the Study Region are contained in Table 18.

Accumulations of water are important to waterfowl habitat and some local uses, such as stockwatering. However, the agricultural production of farmland is considered to be reduced by the presence of the sloughs and potholes which locally receive this drainage. Some drainage processes increase soil salinity by transporting salt to the surface. Extensive networks of artificial drainage channels have been built by farmers or by governments to reduce the problem. During a series of wet years this activity is increased and, in many cases, has raised questions about undesirable effects, such as erosion, impairment of water quality, destruction of waterfowl and wildlife habitat, reduction of quantities of local water needed in dry periods, reduced ground-water recharge, and aggravation of flooding during wet periods.

Ducks Unlimited, in pursuit of its interest in preserving wetlands, attempts to organize its projects so that they are also beneficial to agriculture (Figure 28). The Canadian Wildlife Service and provincial agencies are also actively engaged in programs to preserve wetlands (see, for example, Brewster and Caldwell, 1974).

An indication of concern about drainage issues is exemplified by a major study on the subject begun in 1976 by the government of Saskatchewan, through a public advisory committee. In 1979, the committee held public meetings to consider proposed provincial legislation intended to address drainage problems. Watershed Commissions were proposed for each of seven basins in Saskatchewan, to resolve issues in those basins. In early 1981, the Drainage Control Act was proclaimed. Pending the establishment of commissions, the Act is administered by Saskatchewan Environment.

Figure 28. LOCATION OF DUCKS UNLIMITED 1980 PROJECTS (DU, 1981).


DUCKS UNLIMITED (CANADA)
Location of 1980 Projects
● Project Activities
○ Multiple Project Developments
Edmonton
Calgary
Saskatoon
Regina
Winnipeg

A report by the Manitoba Water Commission (1977) reviewed agricultural drainage in that province, and concluded that provincial policies at that time were inadequate "to meet the changing needs of agriculture or to maintain the present drainage system at its most efficient level", primarily because of lack of cooperation between landowners, municipalities, and the province. It recommended a number of measures, including use of the Conservation District Act as a vehicle for managing drainage efforts.

Examples of specific basin drainage problems are referred to in subsequent sections and in a report by FitzGibbon (1981).

4. WATER QUALITY

The quality of surface waters in western Canada ranges from examples of the exceptionally pristine to those of extreme degradation due to natural or human processes. The use of the terms "natural" and "human", throughout the report, is to distinguish the perhaps more easily managed activities of human populations and is not intended to imply that human activities are not natural.

Processes that change water quality in flowing streams differ somewhat from those affecting the relatively still waters of lakes within a drainage system, and again from those affecting lakes that are the end point of closed drainage basins. It is usually found that water quality concerns, and studies that have addressed them, are specifically related to local situations. A broader overview of some aspects of water quality, which includes this region, is found in a publication of Fisheries and Environment Canada (FEC, 1977).

Precipitation in the Study Region is of very good quality in most areas. However, wind-blown contaminants can reach surface waters from the atmosphere either in solution, or as particulate matter washed out of the atmosphere by precipitation or by settling from the atmosphere without the aid of precipitation. In recent years, contamination of the atmosphere by industrial wastes has become a concern, particularly down-wind of petrochemical, sour gas, oil sands, smelter and pulpmill operations. Sulphur dioxide and nitrogen oxides combine with atmospheric water to form "acid rain", which has had devastating effects on lakes in eastern Canada, and is considered to be a threat to the Canadian Shield lakes in parts of the Study Region. Other airborne materials of concern include organics, such as pesticides and PCBs.

Surface-flowing waters at high elevations usually are relatively pure. As these waters proceed downstream and are joined by tributary systems, they acquire suspended and dissolved erosion products. Where they become the rivers that cross the Interior Plains, erosion products increase due to high carrying velocities and more easily eroded materials. Where the seaward flowing waters in these drainage systems pass through natural lakes or man-made reservoirs, quality characteristics are again subject to change, due to the different physical and biological characteristics associated with lakes and reservoirs. The study of lakes (limnology) has become a relatively advanced branch of the science of hydrology. Because of the fisheries and recreation interests in lakes in the Study Region, more attention has been paid to the examination of water quality in lakes and reservoirs than in the flowing waters of the drainage region. One of the earliest and best known of the Canadian limnologists who has studied water quality aspects of lakes in the Interior Plains was D.S. Rawson. His studies, particularly of lakes in Saskatchewan, served as a starting point for a great many subsequent investigations by government agencies, academics, and private researchers into the processes that influence the quality of lakes.

Natural characteristics and processes are important to the quality of rivers and lakes. One of the fundamental characteristics of the Study Region that has great influence on water quality is the existence of two broadly differing geological bases. In the northeast portion, the Canadian Shield is characterized by hard granitic surface material, so that surface waters contain relatively low concentrations of total dissolved solids (TDS). The low alkalinity waters in the Shield area, however, are more susceptible to the effects of acid rain. In the plains between the Cordillera and the Canadian Shield, surface materials made up of glacial till and lake deposits erode more easily. As a consequence, much higher TDS values occur. Lakes or reservoirs in either of these regions are either long-term or temporary holding bodies for streamflow, and they tend to increase the concentration of dissolved solids if their surface area is large relative to their volume. Suspended solids, however, settle out in the slower moving waters of the larger bodies. In this way, lakes and reservoirs within a river system trap upstream sediment loads which may contain contaminants.

In addition to increases in salt content, natural sources can also be responsible for: contamination of waters by heavy metals (mercury and arsenic, for example), taste and odour effects (oil and sulphur, for example), and perhaps the most generally annoying of water quality problems, the excessive growth of algae and weeds in nutrient-rich waters. In particular, the natural occurrence of phosphates and nitrates, and the summer warming of shallow lakes, has resulted in this form of "pollution" in most prairie lakes throughout recorded history. The process that leads to this is called eutrophication. Waters that are highly fertile are termed "eutrophic", those that are moderately fertilized are "mestrophic", and those that are infertile are "oligotrophic".

Eutrophication can be described as the aging of a lake due to a gradual build-up of materials that stimulate biological growth in the lake. Eventually biological decay consumes much of the dissolved oxygen in the water. Ultimately, a lake becomes filled by sediments entering it in streams and biological material that has grown and accumulated within the lake. The rate of eutrophication depends upon the rate at which nutrients are provided to this system; the presence of heat, light, and other factors important to biological growth; the depth of the lake; the rate at which the waters within the lake are exchanged with any outflow; the rate at which sediment is brought into the lake; and other factors.

Human settlement and industry in western Canada have often developed in locations where water quality was originally quite satisfactory for all needs. This human activity, however, can increase existing types of degradation and impose new ones. For a detailed description of water quality parameters discussed below, the reader is referred to Environment Canada (1979).

Biological contamination results from the introduction of micro-organisms that pose threats to the health of water users. These are introduced into water bodies in effluents containing human and animal wastes. Frequently this type of pollution is identified and measured using counts of total coliform and fecal coliform bacteria, although new approaches are being developed which will identify viral and other biological contamination, even where coliforms have been treated by disinfectants.

Metallic contamination of waters usually results from mining, processing of mined materials, or dredging. Metal concentrations in waters can produce toxic effects on water users. The list of metals of concern includes: aluminum, antimony, arsenic, boron, cadmium, chromium, colbalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, vanadium, and zinc.

Biochemical contamination has been stimulated by human conflict with undesirable vegetation and pests. A variety of biocides have been developed that can harm non-target organisms, including humans. Although agricultural, forestry, and urban spraying of biocides has been of concern for many years, their use is increasing significantly. No-till methods of land treatment for crop farming could result in substantially increased use of biocides. A partial list of biocides presently of concern to water quality managers includes: aroclor, DDD, DDE, DDT, aldrin, BHC, chlordane, dieldrin, endosulphan, endrin, heptachlor, lindane, MCPA, methoxychlor, 2,4-D, and 2,4,5-T. In this report the term "pesticides" is used to include both herbicides and insecticides.

In addition to the categories described above, there exist numerous toxic materials that, through uncontrolled disposal practices or accident, can find their way to surface or ground waters in harmful quantities. Examples are: cyanide, phenols, tannins, lignins, MBAS, surfactants, humic acids, oil, and grease.

The natural occurrence of nutrients, and their role in algae and plant growth, have been described. Human activity can increase nutrient input from "natural" sources through disturbance and manipulation of soil and rock. However, particularly serious nutrient loading of water bodies occurs from the discharge of human and other animal wastes (e.g., sewage disposal and run-off from feed-lot operations), and the usage of nutrient-rich products (e.g., detergents) that end up in waste water effluents. Examples of nutrients are: phosphates, nitrates, and silicates.

Heat is regarded as an important quality parameter, inasmuch as chemical and biological processes are affected by temperature. The effects of natural heating and cooling can be altered by human intervention. For example, altering normal water depths by storage, diversion, or release of water will also alter normal processes of heating and cooling. Waste heat disposal into water bodies is usually a more locally significant process, especially where heat dispersion is slow. Nuclear power generation, which requires large quantities of cooling water, has not yet been developed in western Canada. Thermal (fossil fuel) power plants and some industrial users are present sources of waste heat.

Water turbidity due to organic or inorganic dissolved and suspended materials also affects chemical and biological processes, and can be aesthetically unpleasant. Nevertheless, water-borne material can also serve useful purposes and in the case of delta building and maintenance plays a key ecological role.

The presence of dissolved material in water has various chemical consequences. Acidity (pH) is of interest, because of biological sensitivity (including fish). Salinity, chlorinity, alkalinity, hardness, and total dissolved solids content are characteristics which reflect the solution of many types of material. Examples of ions that are usually measured but did not appear previously are: calcium, strontium, magnesium, potassium, sodium, bicarbonate, carbonate, chloride, fluoride, and sulphate.

Oxygen is essential to life in water. Its presence relies on exposure to the atmosphere and photosynthesis by microscopic plants. Prolonged periods of ice cover can result in depletion of dissolved oxygen. Within water bodies, both chemical and biological oxygen demands occur, both naturally and as a result of human activities. The potential effects of wastes that will undergo oxidation are determined by measurements of their biological and chemical oxygen demands (BOD and COD). Oxygen depletion downstream from a sewage discharge under ice conditions can be a serious problem.

It is clear that possibilities for serious water quality problems, due to both natural and human processes, exist in the Study Region. In general, the waters in the Mackenzie system, which are influenced by relatively small populations and which are replenished by large annual flows, have fewer water quality problems, although some local concerns exist. In the Saskatchewan-Nelson basin, on the other hand, the shallow prairie lakes and sediment laden rivers are often associated with intensive agriculture, larger populations, and industrial centres which create a greater variety of water quality concerns. Some of these concerns are relatively widespread within a basin, whereas others are more local and relate to specific industrial or municipal situations.

Two concepts related to waste effluents are of interest. Although regulatory agencies may prescribe limits for concentrations of particular contaminants, these limits do not apply to an agreed upon zone adjacent to the disposal point, called the "mixing zone", where wastes are allowed some measure of dilution. Another concept is the degree to which receiving waters are considered able to accept contaminants without adverse effects. This "assimilative capacity" is becoming a recognized basis for establishing water quality objectives, though it is not universally accepted as being ecologically sound, because some effects may not become apparent until significant damage is done.

A description of provincial and federal agencies, and their respective responsibilities and roles in water management in the Study Region, is contained in Chapter I.7. Water quality programs include monitoring, regulatory activities, and research. Each province has a set of well-defined water quality objectives or standards. Wallace (1979) considers that the prairie provinces maintain much higher standards for sewage treatment than do some other provinces.

Monitoring networks operated by provincial and federal agencies provide data on the quality of surface waters and the materials transported to waters through the atmosphere. Although federal networks were once widespread, there has been a trend to defer to provincial networks in recent years, except for locations of specific federal interests, such as on federal lands, and at interjurisdictional boundaries. Environment Canada operates a National Water Quality Data Bank (NAQUADAT) and publishes data records that include provincial and federal data (e.g., Environment Canada, 1980). Environment Canada also operates eleven water quality stations at Alberta-Saskatchewan and Saskatchewan-Manitoba boundaries, for the Prairie Provinces Water Board (PPWB, 1981), Air quality networks include the Canadian Network for Sampling Precipitation, the Background Air Pollution monitoring Stations, and the IWD-Organic network (IWD, 1978b).

Manitoba has extensively examined the subject of water quality objectives in that province (Manitoba Environmental Council, 1978; The Manitoba Clean Environment Commission, 1979). The province has proposed four use categories for the classification of stream water quality objectives. This system is unique in the Study Region, perhaps because few Manitoba streams flow to other jurisdictions. Use designations do not have to account for possibly differing requirements in a downstream jurisdiction.

Details of water quality characteristics for each drainage region are found in Part B (Hudson Bay and Missouri River) and Part C (Arctic).

5. GROUND WATER

Ground water is available in much greater quantity than surface water throughout virtually all of the Study Region. Its role in the hydrologic cycle is described briefly in the Appendix. While its natural quality may be inferior to surface waters (e.g., higher disolved solids), it is often available where surface waters are not. This is especially true on farms located a considerable distance from rivers or lakes. Ground water, if used properly, can provide a reliable source that is relatively constant in both quality and quantity.

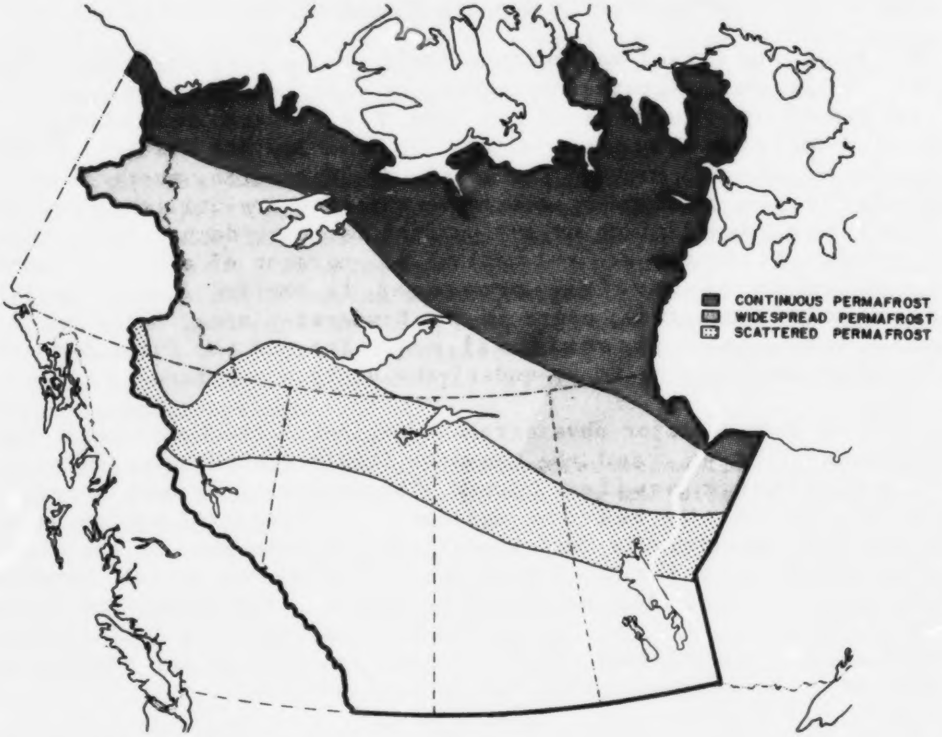
Both surficial and bedrock aquifers are used throughout the Study Region. Figures depicting the location of these aquifers are found in Chapters III.4 and V.4, which describe the ground-water resources in the Hudson Bay and Missouri River drainage areas, and in the Arctic drainage area, respectively. Normally the shallowest available supplies are utilized, but if flows are insufficient or the quality is poor, deeper wells must be dug. Although an estimated 60 percent of all farm rural supplies in the prairie provinces is derived from intertill (surficial) aquifers, users in the Kindersley area, for example, must drill through surficial deposits and the first bedrock formation encountered to an underlying bedrock aquifer.

The three major physiographic regions - the Cordillera, the Interior Plains, and the Canadian Shield - each have their own characteristic aquifer types. The diversity is most strongly reflected in the bedrock aquifers. The regional variation in surficial aquifers is less significant because most of the Study Region was glaciated, although differences exist between non-permafrost, discontinuous permafrost, and permafrost zones (Figure 29). Shallow ground-water movement is inhibited by permafrost conditions, and surficial aquifers in the sub-arctic may not be accessible during the freezing months.

Delineation of ground-water aquifers is a very difficult task. The pattern determined is three-dimensional, and conditions can change substantially over a short distance in any direction. Ground-water quality conditions can also change considerably over short distances. In one instance, Lissey (MLM, 1980) found that the dissolved solids content of an aquifer in Manitoba varied from 186 to 1814 ppm between the recharge and discharge ends of a small flow system whose total length was only 3.2 km. Aquifer thickness varies up to 400 metres and more.

Because the amount of effort expended to determine the extent and nature of aquifers corresponds to the amount of use made of them, knowledge of aquifers in the Saskatchewan-Nelson River basin is the most detailed. Ground-water yields over much of the Cordillera are unknown, and available data on ground-water conditions in permafrost areas are few.

Figure 29. LOCATION OF PERMAFROST ZONES (FEC, 1978A).



Bedrock formations capable of supporting wells that yield more than 0.5 L/s (0.0005 m^3/s) generally consist of sandstone, interbedded sandstone, and coal or carbonate rocks. In many formations, yields of over 40 L/s can be obtained, but typically the yields are less than 2 L/s. The water is used extensively for rural and municipal supplies, as well as for industrial purposes such as the treatment of coal.

Surficial aquifers (aquifers associated with glacial deposits) are often important sources, especially where bedrock aquifers are non-existent or contain water of poorer quality. Gravels deposited in preglacial valleys form important, high-yielding aquifers in Alberta and Saskatchewan. When these valleys cut bedrock formations, composite bedrock-surficial aquifers capable of yielding greater than 40 L/s (0.04 m^3/s) to a single well may be formed. Glacial sediments in mountain valleys, although not as extensive as in the Plains, generally exist beneath the only habitable lands in the Cordillera and may be valuable sources of very good quality water. As mentioned earlier, sand and gravel lenses in till frequently support low-yielding farm wells, and the Regina Aquifer of this type is capable of yielding more than 1000 L/s. Surface deposits established during the final stages of glacial melting are found from southern Manitoba to the foothills and front ranges of the Rockies, and may yield up to 30 L/s. Good water supplies may also be found further north in surficial deposits of the Shield and Interior Plains, but as noted earlier, deposits in permafrost areas are of limited value.

There is a great variety in the quality of ground water, depending on a number of factors such as rock type and length of residence time. Total dissolved solids concentrations typically range from less than 500 ppm to over 5000 ppm, with concentrations of up to 300 000 ppm occurring (about ten times the salt concentration of sea water). Water types vary from bicarbonate, to sulphate, to chloride, sometimes within one formation. Waters high in hardness, chlorides, fluorides, alkali metals, nitrates, salinity, and/or total dissolved solids are quite common and unsuitable for many uses.

The chemistry of surficial ground waters has a much closer spatial variation than that of bedrock ground waters. Of the surficial deposits, surface deposits generally contain the best quality water because they are unconfined and subject to rapid recharge. Bedrock aquifers, and surficial aquifers in hydrologic contact with bedrock, tend to be more highly mineralized.

In general, ground water resources are not affected as drastically by human activities as are surface waters. Excessive withdrawal of ground water is termed "overproduction" or "overdraft". Overproduction is a serious problem in some parts of the United States. This is particularly true in the Plains region between Nebraska and Texas, and in parts of Arizona and California. This problem is not widespread in the Study Region, though a few instances exist that are cited in later sections.

Incidents of ground water pollution are uncommon through most of the Study Region, even beneath heavily populated areas. On the other hand, once an aquifer is contaminated, cleansing is much slower than with surface waters. The widespread use of land for agriculture, sewage disposal, containment of buried storage tanks, etc., has resulted in a number of cases of aquifer contamination. The aquifers most vulnerable are the shallow, unconfined, and highly permeable types. Even deep surficial or bedrock aquifers can be adversely affected by poor well construction and over-pumping, especially if there are many fractures in the upper layers facilitating rapid downward movement of surface contaminants. Pesticides, fungicides, fertilizers, human and animal wastes, hydrocarbons, and industrial chemicals are a few of the common pollutants. As populations grow larger and agricultural and industrial activity intensifies, the potential for ground water pollution will increase.

The management of ground water in the provinces is a provincial responsibility. In British Columbia, no licensing mechanism exists, although procedures are being developed. In Alberta, licensing of ground-water use is a responsibility of Alberta Environment, although other agencies also have responsibilities for data collection, conservation, and deep well licensing. In Saskatchewan, the Environment department is the licensing authority, while the Saskatchewan Research Council has a long history of research and data collection involvement. In Manitoba, ground water is included under the Water Rights Act, and licenses are required for all diversions of ground water except for domestic use.

The federal government has responsibility for ground water in the territories. Historically, federal agencies played a significant role in data collection, resource evaluation, and research in all of western Canada. In recent years, some research continues and there is also some federal work related to Canada-U.S. boundary issues.

PART B.

DRAINAGE TO HUDSON BAY AND THE MISSOURI RIVER

CHAPTER III

WATER RESOURCES

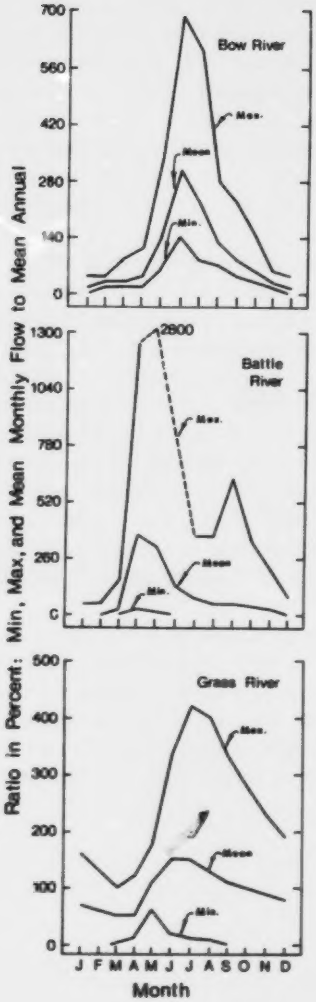


Figure 30. EXAMPLE OF FLOW-RATIO HYDROGRAPHS FOR EACH PHYSIOGRAPHIC REGION, USING COMPUTED NATURAL FLOWS (WER, 1980a)

1. HYDROLOGY OVERVIEW

The rivers in the Hudson Bay and Missouri River drainage systems rise in either the Cordillera, the Interior Plains, or the Canadian Shield regions (see Figure 6). Rivers which typify these three physiographic regions are:

Cordillera	Interior Plains	Canadian Shield
Oldman	Battle	Winnipeg
Bow	Qu'Appelle	Grass
Red Deer(Alta.)	Assiniboine	Cochrane
Clearwater(s.Alta.)	Frenchman	Kazan
North Saskatchewan	Red	Thelon

Flow-ratio hydrographs (see Appendix for definitions of terms) for the Bow, Battle, and Grass Rivers (Figure 30) illustrate some of the differences in the natural flow of the three types of rivers. Other hydrologic statistics related to the natural flow of major rivers in the Hudson Bay and Missouri River drainage regions are contained in Table 19. Detailed information is found in WER (1980a).

The Shield example has the least variability in annual mean flow from year to year, as indicated by the low coefficient of variation. Correspondingly, the maximum and minimum flow-ratio hydrographs indicate that relatively little variation occurs in any month from year to year. Because there is a large amount of natural lake storage, flows in the Shield are also more evenly spread throughout the year, compared to flows in the plains and mountain rivers. The maximum monthly flow usually occurs in June or July, but accounts for only 10 to 20 percent of the total yearly volume. Monthly flows for the period of record are relatively evenly distributed about the mean annual flow, seldom more than four times as great.

Flows in rivers originating on the Plains tend to be much more erratic. Annual mean flows can vary dramatically from one year to the next (as indicated by a high coefficient of variation), and the maximum monthly mean flow for the period of record is typically twenty to thirty times the mean annual flow. Except for the months of the large spring runoff, most of the monthly mean flows are less than the mean annual flow. April flows account for 30 to 40 percent of the total runoff in most years. Flows for any given calendar month can vary dramatically from year to year, as illustrated by the flow-ratio hydrograph for the Battle River.

Rivers originating in the mountains have characteristics intermediate between those of the Interior Plains and the Canadian Shield, but generally are more similar to those of the Shield. The variation in annual mean flow and monthly mean flow from year to year is usually moderate. About 20 to 30 percent of the annual volume runs off in June or July, and about 60 to 70 percent of the monthly mean flows are less than the mean annual flow. The maximum monthly mean flow for the period of record is less than ten times the mean annual flow for most mountain rivers.

Comparisons of flow between the three groups can also be made from a consideration of mean flows for a period of five years. The five-year moving mean plots illustrate that, between 1912 and 1973, the mountain and plains rivers experienced drought periods during the 1930s, with the most extreme five-year drought generally occurring during the 1937 to 1941 period. They also experienced extreme wet periods during the early 1950s. The Shield rivers, however, tended to experience relatively low flows during the early 1950s, with a wet period during the late 1960s.

Details of supply including specific hydrologic details for each individual basin are given later in Chapter IV, together with analyses of supply/demand.

TABLE 19

HYDROMETRIC STATION NATURAL FLOW STATISTICS SUMMARY

(adapted from WER 1980a)

Hudson Bay Drainage	Period of Record	Mean Annual Flow (m^3/s)	Max. Monthly Flow (m^3/s)	Min. Monthly Flow (m^3/s)	Median Monthly Flow (m^3/s)	Median Monthly Flow ★ ★ (m^3/s)	Coefficient of Variation	Ratio[1] Maximum to Mean	Ratio[2] Mean to Median	5 Year Flow Periods Min.	5 Year Flow Periods Max.	Month With Largest Per-Cent of Annual Volume (%)
Red Deer River near Bindloss	(1912-78)	61.9	703	1.0	36.4	70.9	0.49	11.3	1.70	37-41	13-17	June (18)
Bow River below Bassano Dam	(1912-78)	127.8	867	10.9	77.8	149.6	0.25	6.9	1.60	37-41	13-17	June (26)
Oldman River near Lethbridge	(1912-78)	114.8	1005	6.3	54.0	106.3	0.31	8.8	2.13	37-41	50-54	June (30)
S. Sask. River near Lemsford	(1912-78)	301.0	2110	23.6	178.6	360.3	0.28	7.0	1.68	37-41	51-55	June (25)
Clearwater R. near Rocky Mt. House	(1912-73)	24.8	167	3.6	17.1	28.8	0.32	6.7	1.45	18-22	12-16	June (21)
N. Sask. River at Edmonton	(1912-73)	218.8	1206	18.4	131.1	292.1	0.22	5.5	1.67	37-41	12-16	July (22)
N. Sask. River near Deer Creek	(1912-73)	231.8	1342	14.5	149.3	320.9	0.23	5.8	1.55	37-41	12-16	July (22)
Battle River near Unwin	(1912-73)	7.5	212	0.0	2.4	5.5	0.73	28.0	3.16	37-41	52-56	April (32)
Eagle Creek near Environ	(1962-78)	1.7 ★	33	0.0	0.2	0.2	1.00	20.0	8.43	N.A.	N.A.	April (61)
N. Sask. River at Prince Albert	(1912-73)	245.0	1706	1.7	183.3	361.8	0.26	6.2	1.50	37-41	12-16	July (21)
Carrot River near Smoky Burn	(1966-78)	18.5 ★	205	0.0	2.1	3.1	0.64	18.0	8.72	N.A.	N.A.	April (54)
Saskatchewan River at The Pas	(1912-73)	700.2	2924	11.9	563.2	968.4	0.24	4.2	1.26	37-41	13-17	July (19)
Qu'Appelle River near Welby	(1912-73)	8.2	141	<0.1	1.9	3.7	1.10	22.0	3.32	37-41	53-57	May (24)
Assiniboine River at Kamsack	(1912-73)	7.7	266	0.0	0.7	2.3	1.26	37.0	10.9	37-41	21-25	April (36)
Souris River near Sherwood	(1912-74)	3.4	109	0.0	0.3	0.9	0.86	32.4	10.8	31-35	70-74	April (48)
Souris River at Wawanesa	(1912-74)	10.8	226	0.0	2.4	5.9	0.91	21.0	4.59	31-35	70-74	April (31)
Assiniboine River at Headingley	(1912-73)	47.8	478	0.5	17.8	37.9	0.86	10.0	2.68	37-41	53-57	May (27)
Red River near Lockport	(1912-73)	168.3	3293	3.7	63.1	147.8	0.57	19.0	2.66	36-40	66-70	April (29)
Winnipeg River at Slave Falls	(1912-75)	828.5	2298	294.2	754.1	858.0	0.30	2.8	1.10	29-33	68-72	July (11)
Grass River above Standingstone Falls	(1912-73)	55.8	237	3.0	50.2	61.4	0.35	4.2	1.11	52-56	65-69	July (13)
Burntwood River near Thompson	(1912-73)	102.3	508	7.8	75.3	132.0	0.22	5.0	1.36	52-56	68-72	June (20)
Nelson River near Sipiwesk Lake	(1912-73)	2128.9	5269	369.2	2051.1	2489.1	0.23	2.4	1.04	37-41	67-71	August (12)
Nelson River at Warren Landing	(1912-73)	2051.8	4670	321.9	2008.6	2428.7	0.22	2.4	1.02	37-41	67-71	August (12)
Cochrane River near Brochet	(1968-78)	186.2	366	77.6	162.8	189.4	0.18	2.1	1.13	N.A.	N.A.	June (11)
Churchill R. at Isl. Falls Generating Stn.	(1929-72)	682.4	1585	295.8	644.7	714.0	0.25	2.3	1.06	40-44	31-35	July (11)
Thelon River above Baker Lake	(1973-78)	785.5	3172	171.6	480.2	900.5	0.06	4.0	1.74	N.A.	N.A.	June (22)
Kazan River at Outlet of Ennadai Lake	(1963-78)	122.4	377	45.9	107.3	128.9	0.34	2.9	1.14	N.A.	N.A.	July (13)
Gulf of Mexico Drainage												
Milk River at Milk River	(1912-74)	4.2	41	0.0	1.9	2.9	0.56	10.0	2.23	37-41	51-55	April (26)
Frenchman River at International Boundary	(1912-74)	3.0	150	0.0	0.4	1.0	0.77	50.0	7.53	33-37	51-55	April (47)

1 Largest ratio of maximum monthly mean to mean annual.

2 Ratio of mean annual flow to median monthly mean flow for historical period of record.

★ For period March to October.

★ ★ For period April to October.

2. SURFACE WATER QUALITY

Much of the drainage to Hudson Bay via the Nelson River begins in the foothills of the Rocky Mountains, and is supplemented by drainage that originates in the Interior Plains of Canada or flows into the country from the United States. Drainage to the Churchill River system originates in the Interior Plains but is substantially augmented from the Canadian Shield Region. Other Hudson Bay drainage originates in either the Canadian Shield or the Hudson Bay Lowlands.

Beginning in the west, typical values of water quality parameters for water entering the foothills east of the Rocky Mountains are: total dissolved solids (TDS), 70-200 mg/L; pH, 8.0; turbidity, 0-200 JTU (Jackson Turbidity Units); and dissolved oxygen, 10-12 mg/L.

The total dissolved solids in the North Saskatchewan River do not generally exceed 300 mg/L, even though the contribution from the Battle River can reach 600 mg/L. The Oldman River and Bow River contributions to the South Saskatchewan River in southern Alberta are also generally below the 300 mg/L level, and although levels of 500 mg/L are recorded in the Red Deer River inflow, the South Saskatchewan River within Saskatchewan has values generally below 300 mg/L. The Saskatchewan River flowing through eastern Saskatchewan into Manitoba also exhibits this value.

The Qu'Appelle River, which has TDS values of around 400 mg/L in its upper reaches, has much higher values in its central and lower reaches, with 1000-1500 mg/L being commonly recorded. Downstream, the Assiniboine River has lower values, due to dilution by its tributaries above Brandon. Values range from 200-1000 mg/L, with spring runoff values the lowest. The Souris River contributes waters with similar values, though slightly higher in winter months. A comparable range can be found in the Red River; but the Winnipeg River, draining from the Canadian Shield in northern Ontario, has very low TDS values (less than 100 mg/L). The Churchill River has TDS close to 50 mg/L, except for higher values in its Beaver River tributary.

Measurements of specific conductance give an indication of levels of TDS. An approximate relationship is: TDS equals 0.65 times the specific conductance. Median values of specific conductance (and other water quality parameters) for rivers are contained in Table 20.

TABLE 20. WATER QUALITY IN HUDSON BAY AND MISSOURI RIVER DRAINAGE REGIONS (FEC, 1977)

RIVER	SPECIFIC CONDUCTANCE^1	TURBIDITY (JTU^2)	pH	TOTAL PHOSPHOROUS^3
NORTH SASKATCHEWAN R. (EDMONTON)	334	8.5	8.1	L .005
NORTH SASKATCHEWAN R. (PRINCE ALBERT)	438	5.8	8.2	0.10
OLDMAN R. (LETHBRIDGE)	368	6.3	8.1	0.012
SOUTH SASKATCHEWAN R. (SASKATOON)	402	5.5	8.1	0.016
SASKATCHEWAN R. (THE PAS)	424	18.	7.8	0.038
BATTLE R. (UNWIN)	929	7.	8.3	-----
QU'APPELLE R. (TANTALLON)	1624	12.	8.2	0.191
RED R. (SELKIRK)	709	13.	7.8	0.220
WINNIPEG R. (PINE FALLS)	95	5.5	7.7	0.028
NELSON R. (KELSEY)	296	7.4	8.0	0.020
MILK R. (EAST CROSSING BOUNDARY)	471	58.	8.1	0.013
CHURCHILL R. (ISLAND FALLS)	99	1.9	7.6	0.013

NOTES:

L: LESS THAN
(1) - UNITS ARE MICRO-SIEMENS PER CM.
(2) - JTU, JACKSON TURBIDITY UNIT
(3) - MG/L

The same table shows that pH values throughout the drainage region range from about 7.5 to 8.5. However, a survey of 569 lakes in Saskatchewan (Liaw and Atton, 1980) found a range of 6.0 to 10.0, with the neutral to slightly acidic lakes located in the Shield region of northern Saskatchewan. These poorly buffered lakes are the most susceptible to the effects of "acid rain". An account of a number of acid rain situations in this drainage region has recently been provided by Brown et al (1981).

Turbidity values vary with season and with location within this drainage basin. In the mountainous regions, streams and rivers have high flows in the early summer, so that values range from 0 to 200 JTU. As the rivers in the Saskatchewan River system enter the Interior Plains of Alberta, ranges in turbidity values remain high because the rivers erode during periods of high flow. Thus, the range in recorded values of the Red Deer River near Bindloss is 0 to 1050 JTU. However, where rivers are regulated to suppress high seasonal flows, ranges in turbidity are somewhat lower. For example, the values recorded on the North Saskatchewan River vary between 3 and 110 JTU at Edmonton and are less than 30 JTU just inside the Saskatchewan border. Similarly, values recorded on the South Saskatchewan River 30 km downstream from Saskatoon are 20 JTU or less. It must be emphasized, however, that these river systems have not been the subject of lengthy periods of measurement of turbidity. Thus, the values described herein cannot be taken as a sound statistical summary of water quality. In the case of turbidity, however, the values recorded appear to be consistent with what would be expected.

In the region that drains to Hudson Bay, the source rivers in the mountains and foothills generally have very high concentrations of dissolved oxygen. Problems associated with ice cover do not begin to be noticed until the rivers reach the Interior Plains region of Alberta. For example, low values have been recorded on the Red Deer River and in the North Saskatchewan River downstream from Edmonton. The Beaver River, which rises in eastern Alberta, has also been found to suffer oxygen depletion during winter months. For the most part, however, the Saskatchewan and Churchill River systems do not experience serious dissolved oxygen deficiencies during periods of open water, except for instances recorded on the Red Deer River during low-flow periods.

This can also be said to be generally true for the other components of the Saskatchewan-Nelson drainage system. For example, low oxygen values have been recorded in winter months on the Souris River, but during ice-free periods most values are generally high. An exception is the Red River, downstream from the city of Winnipeg, where there has been some indication of oxygen depletion during summer months, probably due to the biological and chemical demands resulting from the discharge of the effluent from the city. Oxygen depletion due to eutrophication (Chapter II.4) in rivers resulting from nutrient enrichment has been a problem, particularly below Calgary, where fish kills have occurred. However, most major cities have adopted or are considering tertiary treatment as a solution to the problem (Chapter VIII.5).

Eutrophication is a wide-spread problem in lakes in the Hudson Bay drainage region, due to both natural and human processes. Lakes used for recreation in the Study Region that presently experience serious algae and weed problems are too numerous to summarize. Increasingly, people are venturing farther from major urban areas and establishing recreation centres around large numbers of previously unused lakes. In later sections dealing with water supply and demand analyses, mention will be made of some instances where major eutrophication problems pose a significant threat to the recreation base of the drainage basins being addressed. Algal growth in farm dugouts is also a widespread problem in the southern drainage basins. Algae in some municipal water reservoirs is another concern.

The presence of some toxic materials in these drainage waters has been a concern. Although the occurrence of mercury in some waters of the Interior Plains is a problem, the complexities of performing precise analyses of mercury concentrations, and misinterpretations of data, have resulted in unwarranted concern in some other instances. The use of mercury in the past in certain agricultural and forestry related activities has resulted in the introduction of the metal into the water environment. In some cases, it has become concentrated in the sediment of rivers and lakes, and has then been gradually reintroduced into the biota of the waters and has become concentrated in fish. A great variety of other toxic materials can be introduced to water systems from different types of industrial activity, including mining and mineral processing. Such instances will be summarized in the later analyses of specific basins.

The use of a variety of pesticides in agriculture, forestry, and urban applications has resulted in the presence of residues of at least 24 types in the waters of this drainage region (Gummer, 1979). Some are widespread (e.g., lindane is found in all the basins). Others are local (e.g., four are found only in the Souris River basin). Although present environmental guidelines are not yet exceeded, the long range cumulative effects on birds, wildlife, fish, and humans are of concern.

Phenolic substances sometimes occur in the waters of this drainage basin in concentrations up to at least ten times the suggested limit for drinking water (FEC,1977). All the major tributaries to Lake Winnipeg have values exceeding the drinking water standard. Sources include a great variety of industrial processes.

3. STANDING WATER

The Hudson Bay drainage region contains numerous lakes, some that are part of the major drainage networks, some that form large closed drainage basins, and large numbers of smaller water bodies that constitute the wetlands. Lakes of the first type are active components of the annual cycle of stream runoff. They are periodically replenished and their quality somewhat reflects that of their upstream sources. In some cases, they act as filters of materials transported to them, which settle out in their sediments. The size distribution of lakes of this type is considerable. Over 130 in the prairie provinces are greater than 100 km^2 in area (Environment Canada, 1973). They are an important element of the major drainage networks, and also constitute the storage of a large volume of fresh water.

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Figure 31. LOCATIONS OF CLOSED DRAINAGE AREAS.

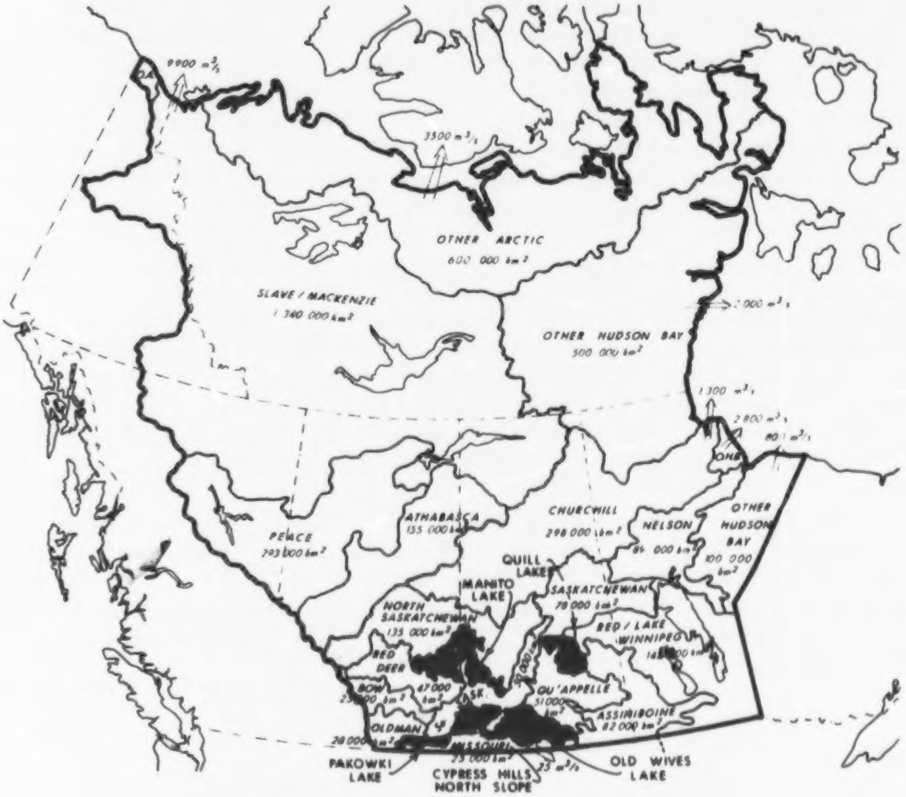

9900 m³/s
3500 m³/s
OTHER ARCTIC
600 000 km²
SLAVE / MACKENZIE
1 340 000 km²
2 000 m³/s
OTHER HUDSON BAY
500 000 km²
1 300 m³/s
2 800 m³/s
800 m³/s
OHB
PEACE
293 000 km²
ATHABASCA
155 000 km²
CHURCHILL
298 000 km²
NELSON
84 000 km²
OTHER HUDSON BAY
100 000 km²
QUILL LAKE
MANITO LAKE
SASKATCHEWAN
78 000 km²
NORTH SASKATCHEWAN
135 000 km²
RED / LAKE WINNIPEG
RED DEER
BOW
47 000 km²
SK.
QU'APPELLE
51 000 km²
ASSINIBOINE
82 000 km²
OLDMAN
28 000 km²
MISSOURI
25 000 km²
25 m³/s
PAKOWKI LAKE
CYPRESS HILLS NORTH SLOPE
OLD WIVES LAKE

TABLE 21. CLOSED DRAINAGE AREAS IN THE STUDY REGION

NAME	BASINS	GROSS DRAINAGE AREA (KM2)		ADJACENT OPEN BASIN*
MANITO LAKE	SULLIVAN LAKE	3 170		NORTH SASKATCHEWAN RIVER
	MANITO LAKE	15 570		
	KIYIU LAKE	4 220		
	BAD LAKE	2 200		
	TOTAL		25 160	
QUILL LAKES	LENORE LAKE	2 590		QU'APPELLE RIVER
	QUILL LAKES	8 750		
	TOTAL		11 340	
CYPRESS HILLS NORTH SLOPE	MANY ISLAND LAKE CRANE L., BIGSTICK L. ANTELOPE L., ETC.		13 750	SOUTH SASKATCHEWAN RIVER
OLD WIVES LAKE	OLD WIVES L., WILLOW BUNCH L., CHAPLIN L. ETC.		24 640	MISSOURI RIVER
PAKOWKI LAKE	PAKOWKI LAKE		5 170	MISSOURI RIVER
	TOTAL		80 060	

* NOT NECESSARILY THE DIRECTION THAT OUTFLOW WOULD THEORETICALLY TAKE.

The Hudson Bay and Missouri River drainage systems include several large closed drainage areas (Figure 31 and Table 21). These have no surface outflow under the most extremely wet foreseeable meteorological conditions. In the supply/demand analyses later in this report, they are included with those open systems identified in the table.

Because there is no outflow from these areas, surface drainage is balanced by evaporation, depending upon interchange with ground-water systems. Thus in wet years the lakes in the basins enlarge, and in dry years, they shrink or disappear. Because of the evaporation process and ground water discharge, the lakes are usually very saline. Considerable study has been made of saline lakes in Saskatchewan, in part to evaluate their economic significance as sources of recoverable salts.

The many thousands of small sloughs or potholes that form the extensive wetlands areas of this drainage region are discussed in the sections dealing with drainage (Chapter II.3), recreation (Chapter VIII.7), and in several of the supply/demand analyses (Chapter IV). They face continuous and increasing competition for other land uses, particularly agriculture.

Lakes and wetlands of all types throughout this drainage region provide water for a variety of uses in all categories. For example, a recent review of uses and conflicts related to uses of Alberta lakes is found in Environment News, a publication of Alberta Environment (1978b). Of the estimated 1600 lakes in Alberta, 630 are considered the "known lake resource". Of these, 269 are considered usable for recreation, 218 good for agriculture, 235 usable as wildlife habitat, and 67 good for sports fish.

Studies related to these uses are usually site-specific, and it would be a ponderous task to itemize, let alone review, all of them. Fisheries and recreation uses have probably generated most of these studies, and examples are available from each of the provincial and federal agencies having interests in these subjects.

In Saskatchewan, lakes have been highly developed for recreation. Sports and commercial fisheries are important industries, and the development of northern Saskatchewan is increasingly providing access to new lakes. The Manitoba lake situation is dominated by its major lakes, but smaller lakes in southern areas are also well developed for recreation. In the eastern portion of the province, the Canadian Shield lakes provide recreation opportunity and domestic water supply for Winnipeg.

The basins draining to Hudson Bay in the Northwest Territories are highly populated with lakes. These are Shield lakes surrounded by continuous permafrost. Their quality is very high and some are important sources of subsistence fishing by local inhabitants.

4. GROUND WATER

General information concerning the nature of the groundwater resource in the Study Region is contained in Chapter II.4. The following gives more specific information for the Saskatchewan-Nelson, Churchill, and Missouri River drainage regions. Very little is known about the resource in the other Hudson Bay drainage, much of which is in the zone of continuous permafrost. For a discussion of ground water in permafrost, see Chapter V.4.

The following describes the various geologic formations present in the Hudson Bay drainage region that represent significant aquifers. It presents the range in the yield of individual wells installed in these aquifers, the range in water quality, and the type and degree of mineralization. The amount of ground water in storage in the reservoirs, however, is not dealt with, and some of the quoted yields may be less than or in excess of "safe yields" (i.e., yields that could be sustained over a long period of time).

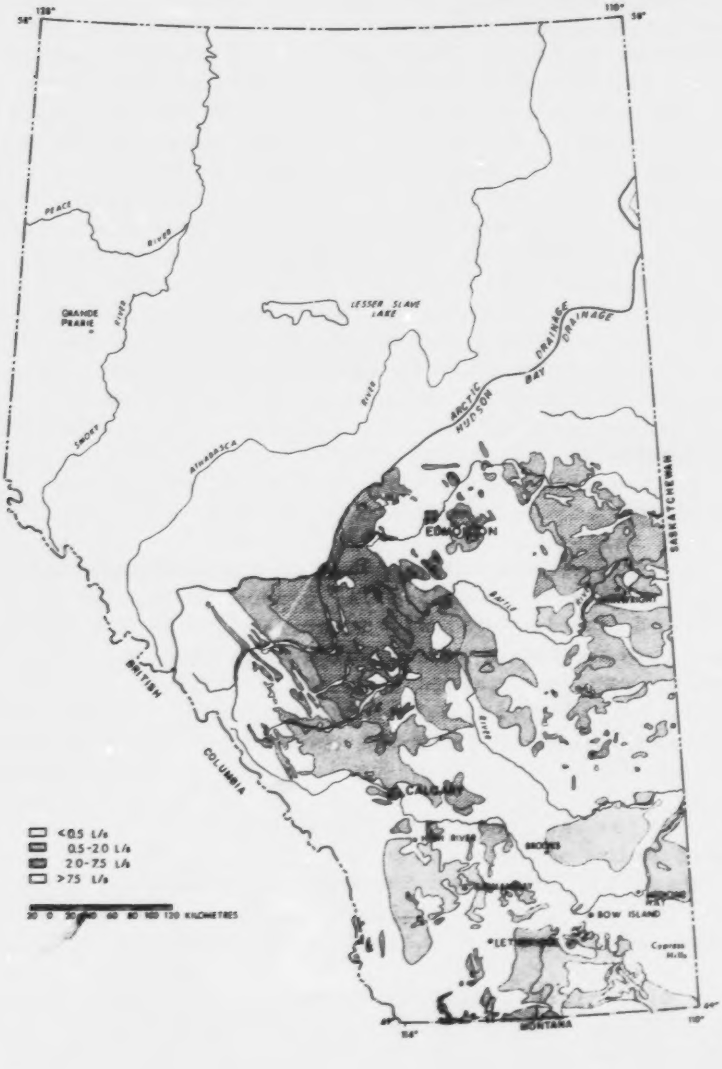
Bedrock Aquifers

Bedrock formations capable of supporting wells that yield more than 0.5 L/s (0.0005 m^3/s) generally consist of sandstone, interbedded sandstone, siltstone, and coal or carbonate rocks. Maps outlining the areas in which single well yields of 0.5 L/s or greater can be obtained from the bedrock in each of the three provinces is contained in Figures 32, 33, and 34. These maps outline yield areas only and these do not always correspond to specific aquifers.

The major bedrock aquifers capable of these yields are discussed below and are summarized in Table 22. Under the column "Water Quality" are shown the observed ranges in total dissolved solids (TDS) for each aquifer (where available) and the ground water type, meaning the principal ionic compounds in the water.

The Milk River Formation is one of the major aquifers in the Missouri River basin of southeastern Alberta. It subcrops (exists at the bedrock surface) near the Montana border and dips in a northerly direction. It is utilized as an aquifer as far north as Bow Island, Alberta.

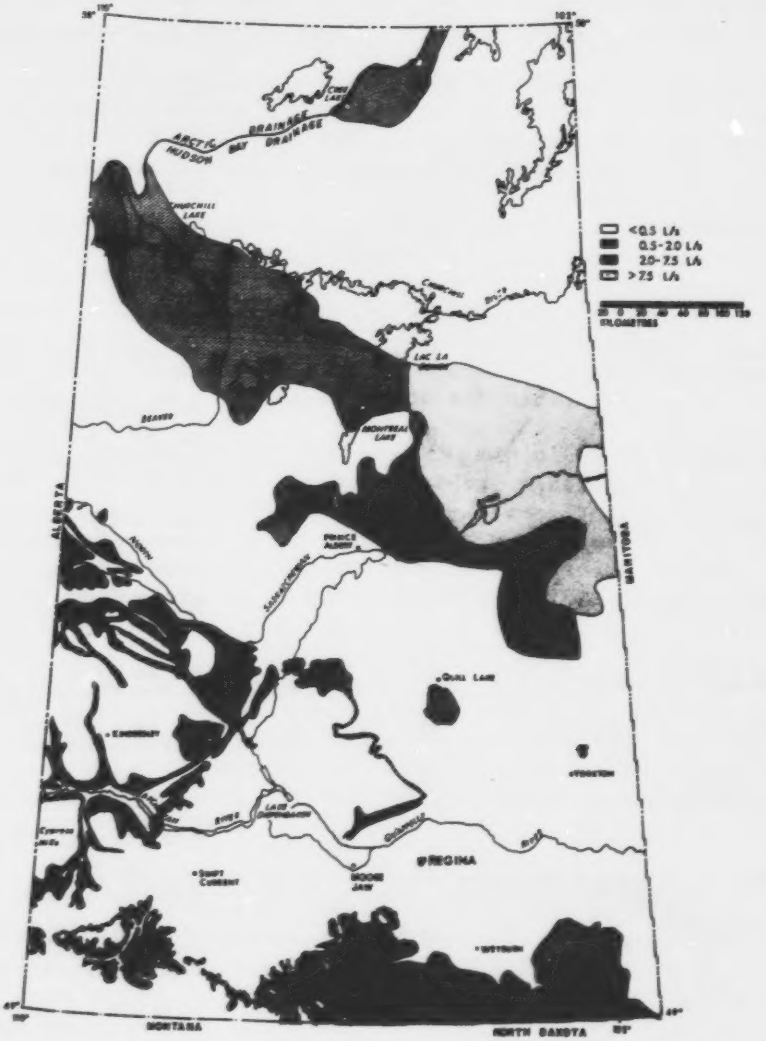
Figure 32. LOCATION OF BEDROCK AQUIFERS IN ALBERTA, BENEATH THE HUDSON BAY AND MISSOURI RIVER DRAINAGE REGIONS (from MLM, 1981).



120°
60°
110°
60°
PEACE
RIVER
GRANDE PRAIRIE
RIVER
SMOKY
LESSER SLAVE LAKE
ATHABASCA
RIVER
ARCTIC
DRAINAGE
HUDSON
BAY
DRAINAGE
EDMONTON
SASKATCHEWAN
BRITISH
COLUMBIA
Battle
River
CALGARY
BOW RIVER
BROOKS
BOW ISLAND
Cypress Hills
MONTANA
49°
114°
110°
49°
<0.5 L/s
0.5-2.0 L/s
2.0-7.5 L/s
>7.5 L/s
20 0 20 40 60 80 100 120 KILOMETRES

The Oldman Formation is the uppermost bedrock unit in the Medicine Hat - Brooks, Alberta area. Wells developed in the Oldman Formation are completed in sandstone lenses (formations shaped like a double-convex optical lens).

Figure 33. LOCATIONS OF BEDROCK AQUIFERS IN SASKATCHEWAN (from MLM, 1981).


ARCTIC DRAINAGE
HUDSON BAY DRAINAGE
CREE LAKE
CHURCHILL LAKE
LAC LA RONGE
BEAVER
MONTREAL LAKE
PRINCE ALBERT
NORTH
SASKATCHEWAN
ALBERTA
MANITOBA
QUILL LAKE
KINDERSLEY
YORKTON
LAKE DIEFENBAKER
QU'APPELLE
REGINA
MOOSE JAW
SWIFT CURRENT
CYPRESS HILLS
WEYBURN
MONTANA
NORTH DAKOTA
<0.5 L/s
0.5-2.0 L/s
2.0-7.5 L/s
>7.5 L/s
KILOMETRES

The Paskapoo Formation of Alberta subcrops in a wide belt east of the foothills between Grande Prairie in the north and High River in the south. Wells in the Paskapoo Formation are generally completed in sandstone beds and the higher yields (Table 22) are obtained where the sandstones are fractured.

TABLE 22. MAJOR BEDROCK AQUIFERS IN THE SASKATCHEWAN-NELSON, CHURCHILL, AND MISSOURI RIVER DRAINAGE REGIONS (M.L.M. 1980)

FORMATION	ANTICIPATED WELL YIELDS (L/S)	WATER QUALITY*
MILK RIVER	0.5 - 40	TDS GENERALLY L 1500 PPM TDS UP TO 4000 PPM TOWARDS NORTH FLUORIDE CONTENT UP TO 6 PPM
OLDMAN	0.5 - 2	TDS G 3000 PPM NA_2SO_4 TYPE HIGH NON-CARBONATE HARDNESS NON-ENCRUSTING WATERS
PASKAPOO	0.5 - 40	TDS: 500-1500 PPM $NAHCO_3$ TYPE
HORSESHOE CANYON	LE 8	TDS: 1000-2000 PPM $NAHCO_3$ AND NA_2SO_4 TYPES LOCALIZED HIGH IRON
WAPITI	LE 2	TDS G 1000 PPM $NAHCO_3$ TYPE
BELLY RIVER (ALBERTA)	0.5 - 40	TDS USUALLY G 1000 PPM $NAHCO_3$ UNPOTABLE IN SOUTHERN ALBERTA
JUDITH RIVER (SASKATCHEWAN)	0.5 - 5	TDS: 700 - 3500 PPM NA_2-MG-$CASO_4$, $NAHCO_3$, AND MG-CA $(HCO_3)_2$ TYPES
RAVENSCRAG	0.5 - 55	TDS: 250-3800 PPM (AVERAGE 1100 PPM) NA_2-MG-$CASO_4$, $NAHCO_3$, AND MG-CA$(HCO_3)_2$ TYPES
FRENCHMAN, WHITEMUD AND EASTEND	0.5	TDS: 1300-4800 PPM $NAHCO_3$, NA_2SO_4, AND NACL TYPES
ASHVILLE - LOWER COLORADO GROUP	0.5 - 2	TDS: 500 - 2500 PPM NO DATA ON WATER TYPE
SWAN RIVER - MANVILLE GROUP	LE 5	TDS: 500 - 2500 PPM NO DATA ON WATER TYPE
RIDING MOUNTAIN (ODANAH MEMBER)	LE 2	TDS: L 200 PPM WATER QUALITY HIGHLY VARIABLE NO DATA ON WATER TYPE
ATHABASCA	0.5 - 2	TDS L 300 PPM NO DATA ON WATER TYPE
CARBONATE AQUIFER	LE 40	TDS: L 500 - G 10 000 PPM DEEPER AQUIFERS ARE SALINE WATER QUALITY HIGHLY VARIABLE
CRYSTALLINE ROCKS	LE 0.5	TDS GENERALLY L 500 PPM WATER QUALITY VERY GOOD
WYNYARD, WOOD MOUNTAIN, AND CYPRESS HILLS	LE 5.5	TDS 500 PPM CA-MG$(HCO_3)_2$ TYPES

NOTES: TDS = TOTAL DISSOLVED SOLIDS
G = GREATER THAN
L = LESS THAN
LE = LESS THAN OR EQUAL TO

The Horseshoe Canyon Formation subcrops in Central Alberta, roughly between the North Saskatchewan River and Carmangay. In the Edmonton area the formation is approximately 410 metres thick. Wells completed in the Horseshoe Canyon Formation penetrate various sandstone lenses in the upper 150 metres.

The Wapiti Formation subcrops northwest of Edmonton and extends in a northwesterly direction to the British Columbia border near Grande Prairie. Water supplies are obtained from the various sandstone and coal beds within the formation.

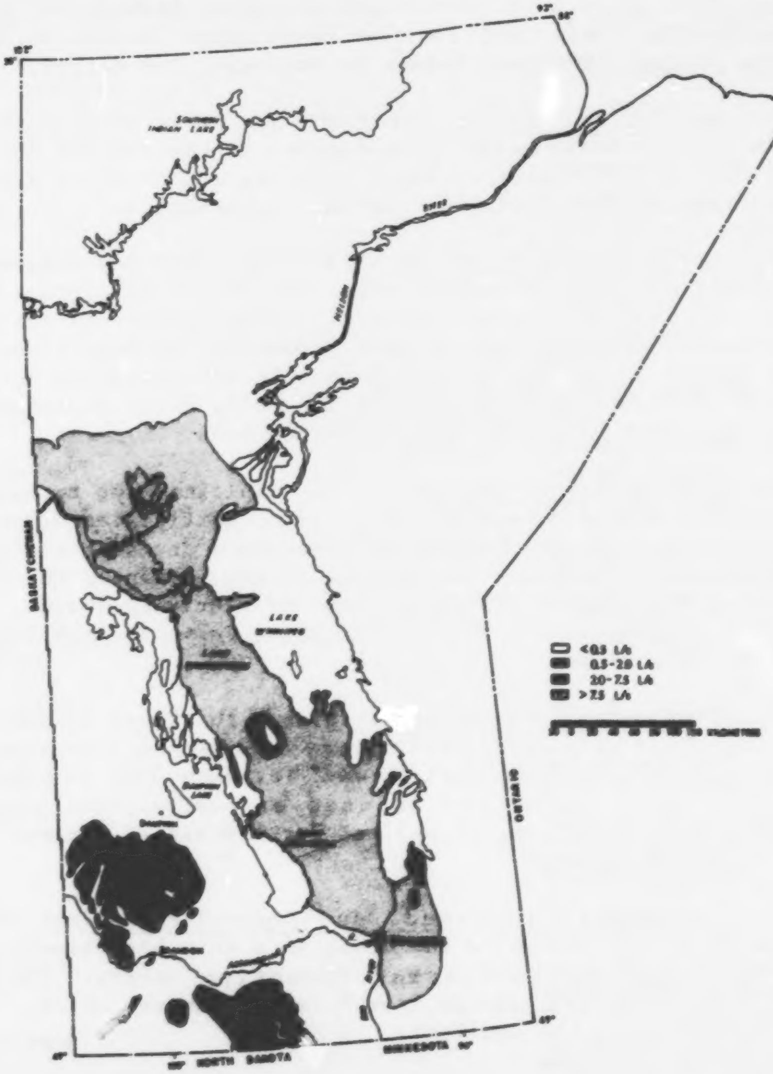
The Belly River Formation is the uppermost bedrock unit in the Wainwright area in eastern Alberta. It is stratigraphically equivalent to the Oldman Formation of southern Alberta. In Saskatchewan the equivalent of this formation has been termed the Judith River Formation to correlate with stratigraphic units in northern Montana. Wells tapping the Belly River Formation are usually completed in one or more sandstone beds.

The Judith River Formation is exploited for rural water supplies in areas where higher yielding surficial aquifers are not available. In the Kindersley area where it is overlain by a less permeable bedrock formation, it may be tapped for ground water supplies by drilling through the overlying shales. Only the areas under which the Judith River Formation subcrops are shown in Figure 33.

The Ravenscrag Formation attains a thickness of 200 m and underlies Tertiary and Quaternary sediments throughout the southern portion of Saskatchewan between 49° and 50° N. Latitude. This formation is used extensively for rural and municipal water supplies, as well as for industrial purposes such as the treatment of coal.

The Frenchman, Whitemud, and Eastend Formations subcrop beneath glacial deposits and drift in a thin band around those areas in which the Ravenscrag Formation occurs. The three formations together may be from 0 top 100 metres thick. Sandy beds may form potential aquifers.

Figure 34. LOCATIONS OF BEDROCK AQUIFERS IN MANITOBA (from MLM, 1981).


SASKATCHEWAN
ONTARIO
LAKE WINNIPEG
NELSON
NORTH DAKOTA
MINNESOTA
<0.5 L/s
0.5-2.0 L/s
2.0-7.5 L/s
>7.5 L/s

The Ashville-Lower Colorado Group of Saskatchewan extends across the province in a northwest to southeast direction, roughly between 56° N. latitude in the west and 52° N. latitude in the east. Hydrogeological data on this group are scarce. However, it appears that well yields up to 2 L/s are possible in places.

The Swan River-Manville Group subcrops in the area between the Ashville - Lower Colorado Group and the Canadian Shield. Well yields up to 5 L/s are thought to be obtainable from silt, sand, and coal beds.

West of the Manitoba Escarpment, the Odanah Member of the Riding Mountain Formation comprises an extensive bedrock aquifer in Manitoba. It is highly jointed, presenting a blocky appearance in outcrop and weathers into light-grey fissile fragments.

The Athabasca Formation is a widespread lithified sandstone occupying a large area of north and central Saskatchewan. Most of the water is available through fracture permeability, but very few data are available.

East of the Manitoba Escarpment, parts of the Winnipeg, Red River, Stony Mountain, and Stonewall Formations, part of the Interlake Formation and part of the Elk Point Formation comprise one large extensive bedrock aquifer, referred to as the Carbonate Aquifer. The part of the Winnipeg Formation included in this aquifer consists of quartzose sand that is up to 30 m thick east of Winnipeg.

Crystalline basement rocks are found in outcrop or beneath the drift in the northeastern part of the Nelson and Churchill River basins. Generally, these crystalline rocks are considered to be poor aquifers, although some water of very good quality may be found associated with fractures, joints, faults, and other breaks. It is unlikely that more than 0.5 L/s is available from this Precambrian bedrock.

Tertiary and Quaternary sediments in the Nelson Basin include: undifferentiated sediments, the Wynyard Formation, the Wood Mountain Formation, and the Cypress Hills Formation, all in southern Saskatchewan. Specific information about these is not contained in Table 22.

The undifferentiated sediments are between 0 and 82 metres thick. Aquifers may be as much as 22 metres thick, supporting wells that may yield up to 5 L/s. The Wynyard Formation in the Quill Lakes area of southern Saskatchewan may yield up to 55 L/s to a single well. The aquifer, which consists of up to 10 metres of fine-to-medium sand, silt and gravel, occupies the lower part of the Wynyard Formation. The Wood Mountain Formation is between 0 and 20 metres thick. It occupies topographically high areas and drains freely via peripheral springs. Because of the distinctive recharge characteristics of the formation, its sustained yield is closely related to the amount of precipitation and is therefore quite variable from year to year. Aquifers in the Cypress Hills Formation consist of thick sequences of gravel, sand, and silt. These cap the upland areas throughout the Cypress Hills in southern Saskatchewan and Alberta. Hydrologically the Cypress Hills Formation is similar to the Wood Mountain Formation.

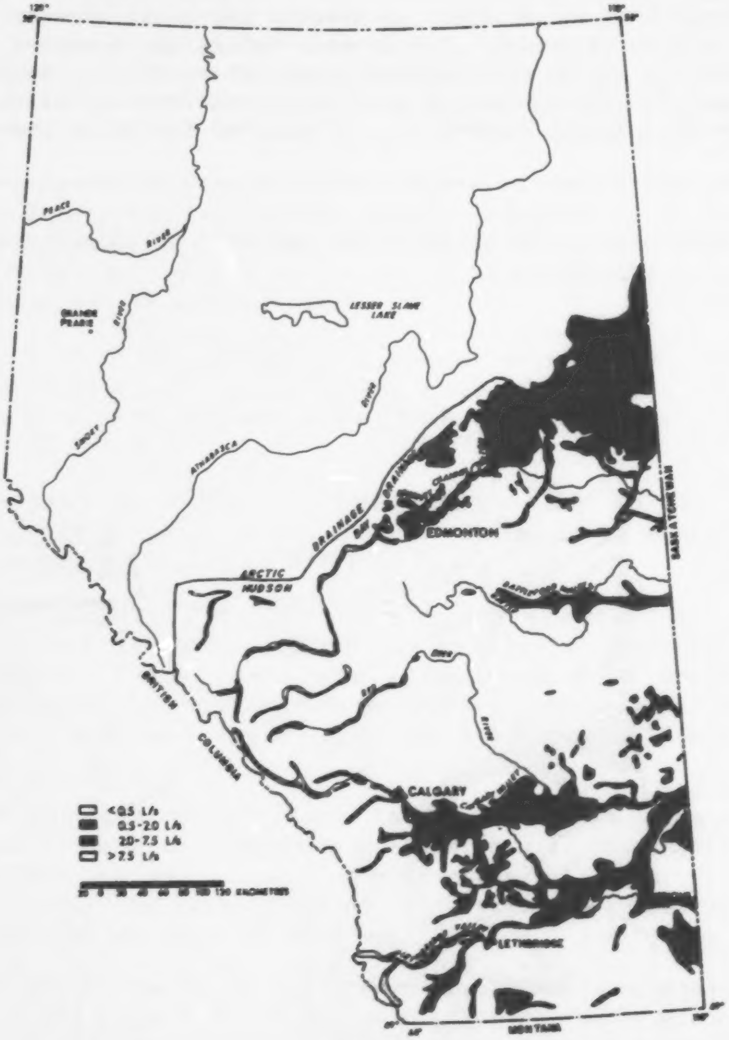
Surficial Aquifers

Surficial aquifers (those associated with glacial deposits) are also important sources of ground water in this region. Their importance increases in areas where bedrock aquifers are non-existent, or where bedrock-derived ground waters are of objectionable quality. A description of the quality of surficial aquifers is found after the following description of geologic formations and yields. Surficial aquifers can be classified as follows:

- Bedrock Valley Fill
  - Preglacial bedrock valleys
  - Glacial bedrock valleys
- Intertill Sands and Gravels
- Surface Deposits

Preglacial drainage was affected by a well-developed pattern of rivers which flowed generally to the northeast. These rivers, where they had their headwaters in sandy or gravelly terrain and where the gradient was high enough to sort coarse-grained alluvium, received and deposited gravels throughout Alberta and Saskatchewan. These sediments, termed the Saskatchewan Gravels (Alberta) and Empress Group (Saskatchewan), are present in many preglacial bedrock valleys. They usually occur beneath thick deposits of glacial drift and form important, high yielding aquifers in those two provinces. The network of preglacial valleys in the three prairie provinces is illustrated in Figures 35, 36 and 37. Because of post-glacial erosion in parts of Alberta, buried preglacial valley aquifers are more important in Saskatchewan than in Alberta.

Figure 35. LOCATION OF SURFICIAL AQUIFERS IN ALBERTA BENEATH THE HUDSON BAY AND MISSOURI RIVER DRAINAGE REGIONS (from MLM, 1981).



PEACE RIVER
GRANDE PRAIRIE
LESSER SLAVE LAKE
SMOKY
ATHABASCA
EDMONTON
ARCTIC
HUDSON
DRAINAGE
BAY
SASKATCHEWAN
BRITISH
COLUMBIA
CALGARY
LETHBRIDGE
MONTANA
<0.5 L/s
0.5-2.0 L/s
2.0-7.5 L/s
>7.5 L/s
KILOMETRES

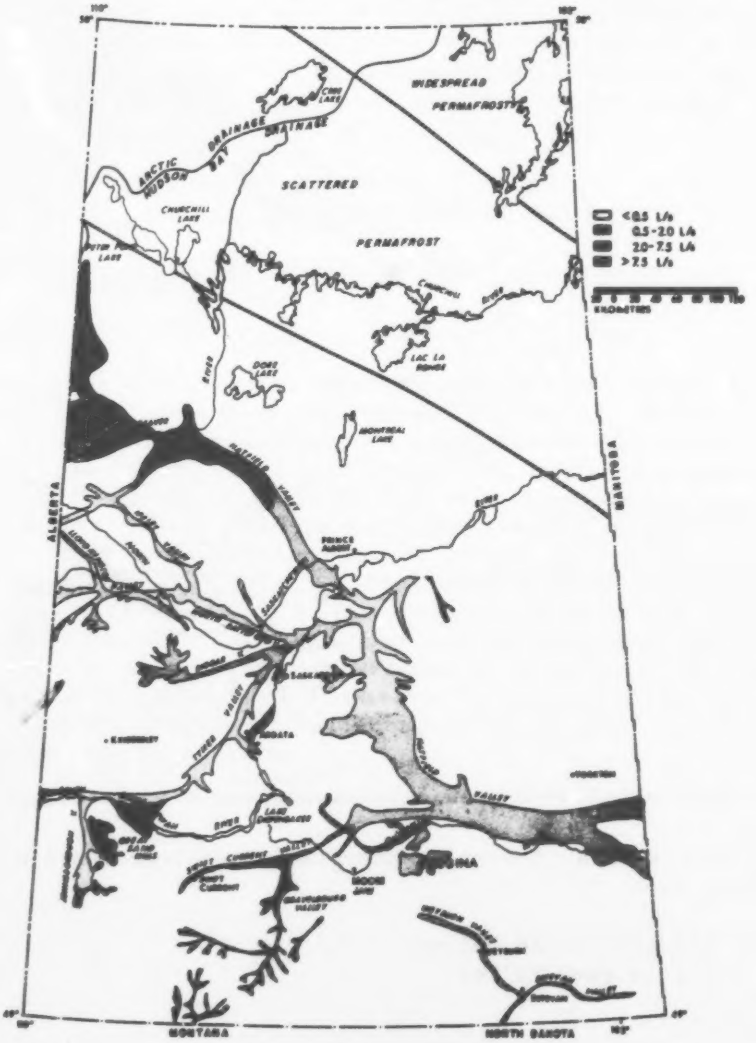
In Alberta, the major pre-glacial valleys containing usable aquifers are:

- the Lethbridge Valley
- the Calgary Valley

- the Battleford Valley, and
- the Beverly Channel System.

Buried valley aquifers in Alberta may yield anywhere from 15 to 90 L/s to a well. The Beverly Valley has a number of major tributaries that also contain important aquifers. Northwest of Edmonton, the Onoway Valley intersects the Beverly Valley. Other tributaries are the Vegreville, Helina, and Vermilion Channels.

Figure 36. LOCATION OF SURFICIAL AQUIFERS IN SASKATCHEWAN (from MLM, 1981).


110°
60°
102°
60°
WIDESPREAD
PERMAFROST
CREE LAKE
ARCTIC
HUDSON
BAY
DRAINAGE
DRAINAGE
SCATTERED
PERMAFROST
CHURCHILL LAKE
CHURCHILL
RIVER
LAC LA RONGE
DORE LAKE
MONTREAL LAKE
<0.5 L/s
0.5-2.0 L/s
2.0-7.5 L/s
>7.5 L/s
KILOMETRES
ALBERTA
MANITOBA
HATFIELD VALLEY
PRINCE ALBERT
RIVER
SASKATOON
YORKTON
REGINA
MOOSE JAW
SWIFT CURRENT
GREAT SAND HILLS
ESTEVAN
MONTANA
NORTH DAKOTA
49°
110°
49°
102°

In Saskatchewan, the Hatfield Valley is the largest, most hydrologically important buried preglacial valley. It splits into two smaller valleys at its southern end. Ground-water yields in one of these tributaries, the Rocanville Valley, are similar to those in the Hatfield Valley, which although variable, are generally high (5-55 L/s). Although an abrupt drop in yield at the Saskatchewan-Manitoba border appears in the Figures, this is due more to a lack of data than to a true documented change in aquifer.

The Tyner Valley is the largest tributary to the Hatfield Valley. Where it cuts the Judith River Formation, a composite bedrock-surficial aquifer is formed, which is capable of yielding more than 40 L/s to a single well.

The Johnsborough Valley is a major tributary to the Tyner. Sediments in this valley also form a composite bedrock-surficial aquifer with the Judith River Formation capable of yields in excess of 30 L/s.

The Domremy Valley, a large tributary to the Tyner, intersects it south of Prince Albert. Sediments here are capable of yielding up to 50 L/s to a well.

The Battleford Valley is a major preglacial valley in west-central Saskatchewan. In the vicinity of Saskatoon, where it joins the Tyner, sand and gravel aquifers are found in numerous major tributaries such as the Redberry, Biggar, Patience and lesser unnamed valleys. Yields greater than 50 L/s can be expected.

The Estevan and Weyburn Valleys cut into Ravenscrag and Whitemud strata in southeastern Saskatchewan. Sediments in the Estevan Valley are capable of supporting wells that yield more than 50 L/s. The Weyburn Valley, with similar yields, joins the Estevan Valley northwest of Estevan.

The Swift Current Valley in southwestern Saskatchewan consists of from 3 to 43 metres of fine-to-coarse grained sand capable of yielding between 5 and 55 L/s. East of Swift Current, the valley falls within the boundary of the Missouri River drainage basin.

The Gravelbourg Valley, within the Missouri Drainage Basin, contains sandy sediments which are hydrologically contiguous to those of the Swift Current Valley so that yields may be similar.

Because of a continued increase in the base level of Saskatchewan rivers since preglacial times, the preglacial valley deposits have been protected from erosion, unlike those in parts of Alberta (see MLM, 1981).

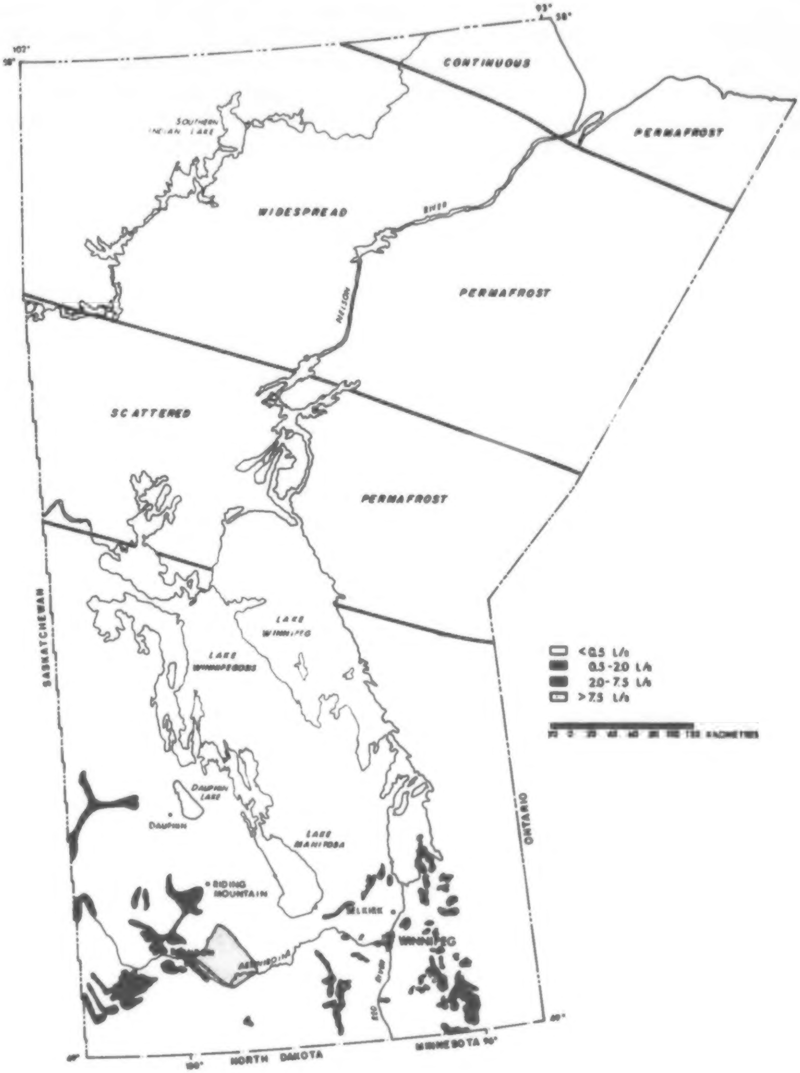
A glacial bedrock valley can be described as one which has been cut into bedrock during interglacial times, filled with alluvium during interglacial periods, and subsequently buried by drift from later glacial readvances. Because the continental glaciers retreated to the northeast, the same direction as the regional drainage system, melt-waters did not flow away from the ice front, but rather drained eastward or formed temporary ice-dammed lakes along the front, so that there was no pronounced sorting or reworking of drift. Exceptions to this are found where local regional drainage was to the south (e.g., the Yarbo Valley in Saskatchewan which contains approximately 100 feet of fluvial gravel).

Intertill aquifers are found throughout the Interior Plains and are extremely variable in hydrologic properties. It has been estimated that 60 percent of all farm water supplies in the prairie provinces is derived from sand or gravel lenses in till, although individual wells so completed are seldom capable of sustained yields in excess of 0.5 L/s. However, these could often yield more if they were designed and completed to meet a larger demand. For example, the Regina Aquifer, described by Lissey (1962), is an intertill aquifer capable of yielding over 1000 L/s. Small to intermediate yields are possible from extensive intertill aquifers in south-central and southeastern portions of Saskatchewan and southern parts of Manitoba. Generally small yields are to be expected in Alberta.

Surface deposits, where associated with glaciation, were laid down during the final phases of glacial melting, and were not covered over by subsequent sedimentation. In other words, the only distinction between these glaciofluvial deposits and the intertill deposits is that the former were not buried by subsequent glacial episodes.

The glaciofluvial environment has contributed to important surface aquifers, such as the Carberry aquifer in southern Manitoba (see Figure 37), which consists of a thick layer of deltaic sands deposited by the ancient Assiniboine River as it flowed into glacial Lake Agassiz.

Figure 37. LOCATION OF SURFICIAL AQUIFERS IN MANITOBA (from MLM, 1981).


93°
58°
102°
58°
CONTINUOUS
PERMAFROST
SOUTHERN INDIAN LAKE
WIDESPREAD
RIVER
NELSON
PERMAFROST
SCATTERED
PERMAFROST
SASKATCHEWAN
LAKE WINNIPEG
LAKE WINNIPEGOSIS
DAUPHIN LAKE
DAUPHIN
LAKE MANITOBA
RIDING MOUNTAIN
SELKIRK
WINNIPEG
ASSINIBOINE
RED
ONTARIO
<0.5 L/s
0.5-2.0 L/s
2.0-7.5 L/s
>7.5 L/s
20 0 20 40 60 80 100 120 KILOMETRES
49°
100°
NORTH DAKOTA
MINNESOTA 95°
49°

===

In the Great Sand Hills area of Saskatchewan (Figure 36), 12 townships are mantled by as much as 27 m of sand and gravel, with a maximum saturated thickness of 24 m. Another important deltaic aquifer is found in the Ardath area of Saskatchewan.

Extensive highly permeable glaciofluvial gravels are found in the foothills and front ranges of the Alberta Rockies, occupying meltwater channels and river terraces in glaciated valleys. These aquifers, in addition to being highly permeable, are replenished by flow systems originating in the front and main ranges of the Rockies. Faults can direct ground water from distant sources to regional and local flow systems. These systems drain through springs in the valley floors, replenishing surficial aquifers, which may be capable of yielding more than 38 L/s to a well.

In addition to glaciofluvial deposits, there are two additional categories of surface deposits: Holocene and aeolian. Holocene alluvium may constitute important aquifers only in very limited areas, adjacent to present-day streams. They may be channel deposits, point bars, or other sediments with a direct hydraulic connection to surface waters. They are typically unconfined, quickly replenished by direct surface water contact, and of a very high transmissivity. Hydrologically, their long term yield can be determined only if the surface-water hydrology of the contributory stream is considered. The foothills and front ranges of the Rocky Mountains contain examples of Holocene aquifers.

Aeolian deposits may form useful aquifers within the Nelson drainage basin, especially where no other form of aquifer can be found. Hydrologic data on these are scarce, however, and it can only be said that, where these deposits are sufficiently coarse-grained, the long-term yield of an aquifer will be practically limited only by the amount of replenishment through precipitation.

Aquifers formed by aeolian sands will be of the unconfined type. Due to the ease with which these aquifers can be polluted, their use as sources of potable water is not encouraged and is closely watched by control agencies.

Water Quality

In ground waters, the degree of mineralization may be related to the following factors:

- initial hydrochemistry of input water,
- aquifer lithology,
- residence time of ground water,
- the interplay of accretion-vs-evaporation,

- chemical aggressiveness of the meteoric water,
- mixing, with connate or other highly mineralized waters,
- oxidation-reduction reactions.

Domenico (as quoted in MLM, 1981) indicates that there is generally an increase in total mineralization of water in proportion to the length and tortuousity of flow path through the aquifer. Within a given system, a major recharge area is characterized by water lower in dissolved solids than in an area where discharge prevails. Recharge areas may be leached of soluble ions, and the absence of chemical reactions prevent the pH of the water from becoming much higher than that of the rain water. It is not uncommon for the ratio of sulphate to chloride to decrease in the direction of flow.

A summary of the water quality of major bedrock aquifers in this drainage region is contained in Table 22. This table contains a column summarizing the general hydrochemical characteristics of each aquifer.

There is a much closer spatial variation in the chemistry of the surficial ground waters in this drainage region than of the bedrock ground waters. This is due to the response of the flow systems to topography, the close interspersion of recharge and discharge areas, and the heterogeneity of the drift.

An overall zonation in the ground-water chemistry of surficial aquifers across the region exists in response to precipitation. In the Interior Plains of Alberta, ground waters are low in total dissolved solids and predominantly of the calcium-magnesium bicarbonate type. Eastward, the average total dissolved solids increases to 2500 in east-central Alberta and central Saskatchewan. Toward southeastern Saskatchewan and southwestern Manitoba, the degree of mineralization decreases again to 2000 ppm in the Riding Mountain area, and to 1000 ppm in the Selkirk, Red River valley areas.

Ground waters in areas where the annual precipitation is more than 45 cm appear to be only moderately mineralized (less than 1000 ppm TDS) and of the calcium-magnesium type. Where the annual precipitation is less than 40 cm, ground waters are more mineralized (1000 - 2500 ppm TDS), and of the calcium-magnesium sulphate type. These major factors may be masked by local conditions, however, such as till mineralogy and permeability, a distinctive bedrock mineralogy (southern Manitoba, Interlake region), nature of the flow system, or topography (Cypress Hills).

Throughout the foothills and mountains of western Alberta, the ground-water quality of surficial aquifers such as Holocene alluvium or glaciofluvial deposits is generally excellent, due to the large amount of precipitation, the high aquifer permeability, and the short flow paths. Waters in these aquifers will be of the calcium-magnesium bicarbonate type, with a TDS of less than 500 ppm. The waters are often observed to be moderately hard due to their travels through fractured bedrock in the adjacent mountains prior to discharge into the valley floors. The gravels comprising the aquifers themselves will also ensure calcium saturation and the consequent hardness of the ground waters.

Buried preglacial bedrock valley aquifers on the prairies often yield highly mineralized waters due to their hydraulic connection to the valley or intertill aquifers, and sulphate will tend to dominate the anions. The water quality may, however, be a composite of bedrock and drift chemistry in situations where the buried valley aquifer acts as a great subsurface drain, taking water from all adjacent sources. The total solids concentrations may vary from less than 500 to greater than 5000 ppm.

Glacial bedrock valleys, where they contain gravels in contact with bedrock (as discussed above), will probably yield water of similar quality to that of the preglacial-type valley. The waters may contain slightly more calcium and magnesium, due to the calcitic nature of the glacial gravels. There is, however, a dearth of specific data for this type of bedrock valley aquifer.

Intertill aquifers generally contain water of better quality than preglacial valley aquifers because they are situated in smaller flow systems, closer to points of recharge. Their waters are usually of the calcium-magnesium bicarbonate type, except where precipitation is very low, or where discharge is predominant. In the latter case, sulphate tends to dominate the anions. The waters are generally quite hard, due to their calcium and magnesium content. Iron, while variable, may be quite high. In southern Manitoba, intertill aquifers contain highly mineralized water due to discharge from the underlying formations. In the Interlake regions, the shallow ground water regime is also highly mineralized.

Surface deposits contain the best quality water in the drainage region because they are unconfined and therefore subject to rapid recharge. These deposits in the front ranges of the Rockies, the foothills, and in parts of the plains region probably contain water with a total dissolved solids concentration of less than 500 ppm, with a low to moderate hardness, and with calcium-magnesium bicarbonate as the dominant ion pair. Iron may surpass the recommended limit of 0.3 ppm in certain aeolian and glaciofluvial deposits. Chloride and sulphate concentrations are very low.

Effects of Human Activities

A variety of developments in this drainage region locally affect the quantity and quality of water in aquifers. Although water depletion is a more probable concern, due either to withdrawal for usage or dewatering of excavations, elevation of the water table can also result. For example, construction of a cooling water reservoir for a thermal power plant on the East Poplar River in southern Saskatchewan caused a rise in the local water table. At the same time, nearby dewatering of the project's coal mine resulted in a depression of the water table, and some concern about well depletion (IJC, 1979).

A more widespread example of some concern in Alberta (ECA, 1979b) is the domestic overproduction of the Milk River aquifer, where both over-development and wastage are documented.

Ground water is less easily polluted than is surface water. It moves slowly and benefits from protective natural filtering and purification, both during recharge and movement through an aquifer. However, it is also far less easily restored once polluted.

The contamination of an aquifer in its most sensitive state - unconfined, highly permeable, inert, and under recharge conditions - can be prevented only by precautionary measures aimed at controlling the location of potential sources of pollution over such sensitive areas. Sources of contamination related to agricultural, residential and industrial activities in the Interior Plains region are listed below:

- biocides
- fertilizers
- animal wastes
- sewage
- petroleum products
- industrial chemicals
- brine
- acids

In conjunction with population growth, trends toward increased uses of chemicals in agriculture, intensification of land use, and industrial growth, threats to ground water volumes and quality are increasing. A high priority has been placed on the need for research on virtually all aspects of ground-water quantity and quality. Concerns for the future are the increasing

- deep well disposal,
- above-ground storage and retention of wastes,
- acid rain,
- petroleum storage, and
- brine and other holding ponds.

Chapter IV

Analysis of Supply and Demand

1. INTRODUCTION

The following supply/demand analyses are intended to describe present limitations to water uses in each individual drainage basin, due either to supply or quality problems. Foreseeable new constraints are also identified, based upon expected changes in water needs. In both cases, water limitations are described within the context of water supply and quality statistics for the specific parts affected in each basin.

Several precautions are necessary for the interpretation of these analyses. First, it is important to understand the dangers of simply comparing total supply with total water requirements, for any drainage region. If water demands were so located within a basin that the most efficient uses of water occurred, then basin totals might be more meaningful. But very often water needs are fixed to specific locations, and these are not always where water supply is greatest in any basin. However, if total basin demands are close to total basin supply, then it is clear that constraints are highly likely.

Second, it is necessary to keep in mind the significance of water "withdrawal" and water "consumption". Withdrawal quantities are volumes of water that must be available to a user, even though some or even most of the water may be returned after usage. Consumption quantities are the net losses to the supply source after usage and are an indication of the effects of a usage on the supply that is left available for downstream users. If consumption losses are low, the same water can be used repeatedly in a drainage system, sometimes by the same user, subject to the effects of the use on water quality.

Third, it must be realized that consumption volumes identified for each use very often do not represent the total effect of a water user on the water resource. Water storage and conveyance bodies (reservoirs, canals) lose water due to evaporation and seepage, for example. These effects are not always known for inclusion in consumption totals. Also, some water uses require large volumes of additional water to dilute their wastes. These effects are very difficult to include in supply/demand analyses of this type. In the latter case, it is usually more convenient to assess water quality trends and locate the sources of specific pollution problems.

Fourth, data of both supply and demand require careful handling. Because great time and space variability exists in both sets, it is necessary to work with statistical summaries which can be misleading, if too much is inferred from their application.

Fifth, constraints on "instream" uses or requirements must be considered somewhat separately from "offstream" uses. Water quality can be of greater significance to instream uses, such as sports fishing, than for offstream uses where treatment is often possible. Quantity aspects for instream uses are often referred to in terms of "minimum flows" necessary to sustain the use. Minimum flow values can differ from season to season, depending upon the use being protected (e.g., spawning, fish migration, water quality, and water-borne transportation). There may also be a need to ensure against rapid fluctuations in flow to protect some instream uses.

Some background information for the following analyses is provided in other sections, namely:

- characteristics of the region (Chapter I)
- characteristics of the water resources (Chapters II,III,and V).

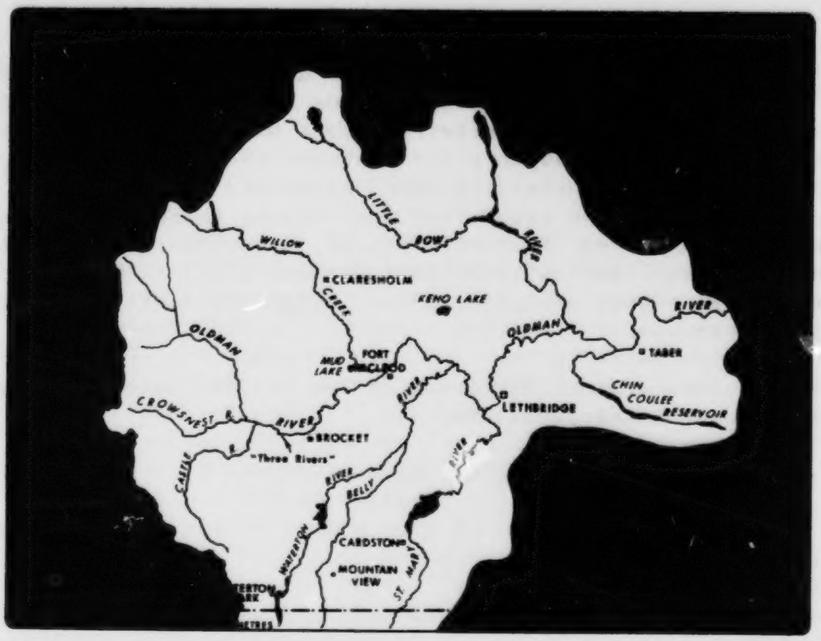
Readers interested in more information about water use than is included in this section are urged to refer the following:

- water-related characteristics of use categories (Chapter VII), and
- specific water use information for the Study Region (Chapter VIII).

Finally, the term "regulated" is used in the following sections to indicate where streamflow has been altered from its natural pattern. This can be due to damming, diversion, and other flow control measures on either the main stem or upstream tributaries. It can also be due to addition of flows from other streams, such as irrigation return flows draining to a stream other than the one from which they were drawn. This term is used in Environment Canada streamflow records to distinguish such altered flows from "natural" flows.

The detail of presentation in the sections that follow is not uniform from basin to basin because of wide variations in existing and potential demand. For example, the South Saskatchewan River basin was treated as several sub-basins, whereas some much larger basins are treated as a unit.

Figure 38. THE OLDMAN RIVER BASIN


LITTLE
BOW
RIVER
WILLOW
CLARESHOLM
CREEK
KENO LAKE
RIVER
OLDMAN
OLDMAN
FORT
MUD
LAKE
MACLEOD
TABER
CHIN
COULEE
RESERVOIR
CROWSNEST
R.
RIVER
BROCKET
LETHBRIDGE
CASTLE
R.
"Three Rivers"
RIVER
RIVER
RIVER
BELLY
WATERTON
CARDSTON
MOUNTAIN
VIEW
ST. MARY

2. OLDMAN RIVER BASIN

The Oldman River basin drainage (Figure 38) consists of the Oldman River and several important tributaries. The river rises high in the Rocky Mountains of southern Alberta, and is joined by the Crowsnest and Castle Rivers in the foothill country. As far downstream as Brocket, the system is presently unregulated, so that the three rivers to that point are "wild rivers". Downstream from Brocket, the Oldman River is joined by Willow Creek, and the Belly, St. Mary, and Little Bow Rivers, on each of which irrigation diversion works have been developed.

The full complexity of canals, reservoirs, and other works in this basin is described in Chapter VIII.2, which details the irrigation systems. Downstream from a diversion near Brocket to the Lethbridge Northern Irrigation District, the river is considered to be regulated. The Oldman River joins the Bow River about 85 km east of Lethbridge to form the South Saskatchewan River.

TABLE 23. FLOW STATISTICS (M^3/S) FOR SELECTED POINTS - OLDMAN RIVER BASIN
(EC, 1980A; WER, 1980A)

RIVER	HYDROMETRIC STATION (PERIOD OF RECORD)	MEAN ANNUAL	LOWEST ANNUAL	HIGHEST ANNUAL	LOWEST MONTHLY	HIGHEST MONTHLY	MIN. 5-YR MEAN	MAX. 5-YR MEAN
OLDMAN -	BROCKET[1] (1967-79)	42.1	15.7 (1977)	66.1 (1972)	4.5 (NOV/79)	305 (JUNE/67)		
	FORT MACLEOD[2] (1912-47*)	38.3	8.1 (1944)	75.1 (1927)	0.8 (AUG/36)	446 (JUNE/23)		
	LETHBRIDGE[2] (1912-75*)	93.0	27.2 (1944)	195 (1927)	6.5 (FEB/36)	941 (JUNE/48)		
	LETHBRIDGE[3] (1912-75)	114.8	45.5 (1944)	230.2 (1951)	6.8 (FEB/36)	1005 (JUNE/53)	78.1 (1937-41)	161.5 (1950-54)
WATERTON -	WATERTON PARK[1] (1908-79*)	18.8	9.9 (1977)	27.7 (1927)	1.3 (DEC/52)	171 (JUNE/08)		
BELLY -	MOUNTAIN VIEW[2] (1912-79)	8.9	4.3 (1977)	14.2 (1927)	0.7 (JAN/49)	69.3 (JUNE/75)		
ST.MARY -	INT'L BDRY.[2] (1903-79)	21.4	9.3 (1944)	38.4 (1908)	1.2 (FEB/36)	212 (JUNE/08)		

1. RECORDED FLOWS - NATURAL
2. RECORDED FLOWS - REGULATED
3. COMPUTED FLOWS - NATURAL

* DISCONTINUOUS RECORD

===

The Oldman River basin has been the subject of considerable study over the past several years. Water issues there are related primarily to irrigation, but there is also concern about environmental, social, and recreational aspects of water use. Studies and/or public hearings have been undertaken by Alberta Environment, the Oldman River Study Management Committee (ORSMC), the Environment Council of Alberta (ECA), the Advisory Committee on Water (ACW), and several other agencies.

Present and foreseeable water demands for each use category have been described in Chapter VIII. The most significant withdrawals and consumptions in this basin are for irrigation. There are no large municipal and industrial demands. The impacts of all water uses, and relationships between uses are evaluated in conjunction with the following description of surface water supply.

Of the total flow in the Oldman River (Figure 38), about 40 percent is due to the upper tributaries, 35 percent is due to the Belly and Waterton Rivers, and 25 percent is contributed by the St. Mary River. A summary of flow data at several points in the basin is presented in Table 23. The information for Brocket describes the hydrology of the unregulated portion of the main river. Fort Macleod was selected to describe the river downstream of the first major irrigation diversion. Locations on the Waterton, Belly, and St. Mary Rivers are included to illustrate the flows in the two major tributary systems that join from the south. Finally, the information for Lethbridge describes the river at a point downstream of all major irrigation diversions.

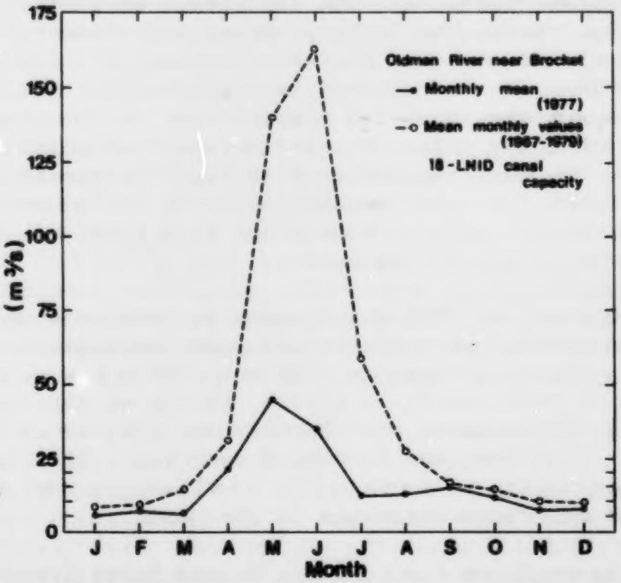
Upstream of Brocket, the unregulated upper reaches are attractive for recreation, particularly because of the natural populations of game fish. At Brocket, the lowest flows occur in winter, and the highest in summer months. The variation from year to year can be great. The highest annual mean (1972) was over four times the lowest annual flow of 15.7 m^3/s (1977). The highest monthly flow, however, in June 1967, was about 70 times the lowest monthly flow in November 1979, reflecting both seasonal variation and changes from year to year. The Brocket data began to be recorded only in 1966. In earlier years, just downstream near Fort Macleod, the lowest natural annual flow computed by the SNBB (1972) was 13.8 m^3/s (1944). This value can be used as an indicator of very dry year conditions in this part of the basin. This natural flow compares to the recorded flow at that point of 8.1 m^3/s.

TABLE 24. RECORDED FLOWS (m^3/s) AT BROCKET AND THE LETHBRIDGE NORTHERN IRRIGATION DISTRICT CANAL AT MENZAGHIES BRIDGE (POINT OF DIVERSION) - 1977

	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT.	OCT.	NOV.
BROCKET	6.2	21.2	44.7	34.5	12.6	13.4	15.4	11.9	7.6
LNID CANAL	0	8.3	15.3	16.7	12.0	11.9	11.2	3.8	0

Between Brocket and Fort Macleod, water is diverted to the Lethbridge Northern Irrigation District (LNID). Because local internal storage is presently limited (in Keho Lake), a large withdrawal is necessary from the Oldman River during the irrigation season. In a recent dry year (1977), the total volume of water withdrawn for the LNID was equivalent to an average flow of 11.3 m^3/s for the period April through October. Greater flows could not be diverted during the high-flow months of May and June (Table 24) because the canal capacity is limited to about 18 m^3/s. A comparison of monthly flows at Brocket for 1977 and average flows for the period 1967-1979 is shown in Figure 39. Thus, the diversion required during the very low flow months of July and August severely taxed the ability of the river to meet demand. In this case, irrigation had to be limited to 99,000 acres (40 000 ha), the maximum possible with the water available. This compares to the 116,000 acres irrigated in 1979.

Figure 39. COMPARISON OF OLDMAN RIVER MONTHLY FLOWS IN 1977 WITH THOSE AVERAGED OVER 1967-1979, NEAR BROCKET.



Still using 1977 as an example of a very dry year, it should be noted that the estimated return flow from the LNID diversion was less than 10 percent of the withdrawal. Thus, of the average flow of 22 m^3/s at Brocket, April through October, there was a net consumption due to the LNID of about 11 m^3/s (equivalent to 6 m^3/s if averaged over the year).

Estimates of future irrigation potential in the LNID vary (see Chapter II.2). The ECA (1979c) suggested that costs and other practical considerations would limit expansion to between 28,500 and 57,000 additional acres (11 500 ha and 23 000 ha), and that this could be accommodated by offstream measures. In a report for Alberta Environment's South Saskatchewan River Basin Planning Program, UMA (1981) estimated an expansion of 60,000 acres within the district. The ECA has suggested that expansion outside the district in this part of the basin is less feasible.

One of the factors influencing the amount of water that can be diverted from the river is the need to maintain an appropriate minimum flow in the river downstream. The minimum desirable flow recommended by the ORSMC (1978) was about 3.8 m^3/s, although others have recommended more than twice that.

As measures to improve water supply to the LNID, maintain desirable flows downstream, and facilitate more efficient use of water in the basin, the ORSMC proposed improvements to the LNID conveyance system and also the construction of a dam upstream of the LNID. The dam was opposed by organizations concerned about its effects on the flows and temperatures of the three upstream rivers, which could affect recreation and fish populations. The ECA opposed the dam, suggesting that the enlargement of the Keho Lake reservoir (in the design stage), enlargement of the conveyance canal, and construction of a reservoir at Mud Lake would meet present and future needs.

Nevertheless, in 1980 the Alberta government committed funds for the conveyance improvements and approved construction of the dam, to be operational between 1990 and 1995. The preferred site is at a point known as Three Rivers, though an alternate site on the Peigan Indian Reserve near Brocket was also under study as of late 1981. The dam and increased conveyance efficiencies will enable an irrigation expansion similar to the ECA and UMA estimates and the recommendations of the ORSMC.

Downstream from Brocket, the Oldman River is joined by the Belly River. The Belly and its tributary, the Waterton River, are both unregulated as they cross the international boundary to the south. Observed flow data for the Waterton at Waterton Park are contained in Table 23. The low winter and high summer flow pattern is again evident. A mean annual flow of 19 m^3/s, and the lowest recorded annual flow of about 10 m^3/s are of significance to the planning of storage for irrigation diversions that begin at Waterton Reservoir (Chapter VIII.2). The mean annual flow of the Belly River near Mountain View, just downstream of its first irrigation diversions, is about 9 m^3/s.

The Belly River supports diversions to the foothills irrigation districts (United, Mountain View, Leavitt, and Aetna). The ECA (1979c) did not note any urgency for increased expansion in these districts, pointing out that users are generally marginal irrigators. Alberta Agriculture suggests a 10 percent increase may occur by 1990. The UMA report suggests a total potential of 52,000 acres as compared to the 45,000 acres presently assessed. Pedology Consultants (1981), in their report to the Advisory Committee on Water, has indicated a total "irrigable" acreage in these districts of 73,600 acres. This estimate would require a diversion of about 60 percent more water than is presently diverted during a dry year. However, this assumes a continuation of present very low efficiencies, which would be unlikely if steps were taken to extensively expand irrigation in these districts.

Water from both the Belly and Waterton Rivers is diverted eastward to the St. Mary Reservoir on the St. Mary River for eventual use in the St. Mary Irrigation Project. The details of these transfers are described in Chapter VIII.2. The amount of water that can be diverted depends upon use of water in the foothills districts, reservoir and canal losses, and desirable minimum flows farther downstream in the Waterton and Belly Rivers. Present minimum flows in each of the two rivers below the diversions is about 0.8 m^3/s. The ORSMC recommended values of 2.3 m^3/s and 0.9 m^3/s, respectively, for these rivers, to protect fish resources and recreation. The ECA, however, recommended no increase from 0.8 m^3/s, on the grounds that "the anticipated benefit is not considered adequate when balanced against the increase in irrigated land...".

The St. Mary River is regulated prior to crossing the international boundary (see Chapter II.2). The mean annual flow at that point is about 21 m^3/s while the lowest recorded flow was less than 45 percent of this value (Table 23). This river flows into the St. Mary Reservoir which is also supplied by the diversions from rivers to the west for use in the St. Mary River Irrigation Project.

The St. Mary Project includes the Magrath (MID), Raymond (RID), St. Mary River (SMRID), and Taber (TID) Irrigation Districts. Several key offstream storage reservoirs are used in addition to the St. Mary and Waterton Reservoirs. In the dry year of 1977, water diverted for use in the Project was equivalent to a mean annual flow of about 19 m^3/s, almost 90 percent of which was consumed.

Pedology Consultants estimated a total developable acreage of about 430,000 acres in the St. Mary Project, compared to the 400,000 acres (160 000 ha) now irrigated. The UMA report estimates a total potential of 550,000 acres within the district. Both reports also suggest that additional land outside the district is irrigable in this part of the basin.

Alberta Agriculture has suggested that the St. Mary Project could expand by 15-20 percent by 1990, and eventually by 50 percent, using available water. The ECA (1979c) suggested that irrigation expansion in the MID and RID should not be encouraged. Irrigation efficiencies in these districts are low (18-21 percent) and more suitable land for irrigation is available to the east. A number of changes to conveyance and storage systems were recommended for the other districts which would increase the irrigated acreage by 15-25 percent, depending on measures taken to increase offstream storage. One possibility is to pump water from the Oldman River for storage in Chin Coulee Reservoir (see Figure 82). This "Chin Pump" development would rely on storage at the dam upstream of the LNID. It received Alberta government approval in 1981, but is not to be constructed until the dam is operational. The ECA had recommended against both the Chin Pump and the dam, mainly for economic reasons. Thompson (1981) also has questioned these projects, in part on economic grounds, suggesting that the costs of pumping would require perpetual subsidization. The Alberta government, however, has felt that these decisions are consistent with its policy decisions "concerning the management of water resources, the need to rehabilitate existing irrigation systems, and the requirement of future expansion" (Cookson and Schmidt, 1981).

Downstream of the St. Mary Reservoir, there are no additional diversions to irrigation districts. The present guideline for minimum flows in this part of the river is 0.8 m^3/s. The ORSMC recommended an increase in this value to 2.7 m^3/s on the basis of support for fisheries habitat. The ECA again recommended no increase over 0.8 m^3/s.

In addition to the irrigation districts described above, private irrigation takes place throughout the basin. Developments are widespread, but are usually located adjacent to the river and major tributaries. Volumes of water used are not large and are difficult to assess. Of the estimates made for future development of private irrigation, the largest total is only 80,000 acres.

Finally, it is necessary to summarize possibilities for additional formal irrigation developments outside of the present irrigation districts. Pedology Consultants estimated that there are about 58,000 acres (23 500 ha) of "actually developable" land in high need areas, 715,000 acres in moderate need areas, and 790,000 acres in low need areas outside of the irrigation districts in this basin. An additional 1.4 million acres (560 000 ha) of actually developable land is estimated to exist outside irrigation districts in the South Saskatchewan River basin, some of which would require water from the Oldman River basin. UMA estimated that there are about two million acres of potentially irrigable land in land classes I to III outside the irrigation districts in this basin.

Downstream from the confluence of the St. Mary and Oldman Rivers, the only existing offstream water requirements are for light industry and municipalities, notably the city of Lethbridge. The latter presently consumes an average of about 0.5 m^3/s which is about 60 percent of the total basin municipal requirement and about eight percent of the lowest recorded monthly mean flow at that point. Industrial demands are even smaller. Both categories are expected to double their requirements by the year 2001.

The ECA and the City of Lethbridge have both recommended minimum flow of about 10 m^3/s near Lethbridge for the city's water supply system. Others have recommended higher values. The Alberta Department of Recreation, Parks and Wildlife, for example, has recommended 20 percent of mean annual flow between October and March, and 40 percent during April to September (ECA, 1979c). These would amount to about 23 m^3/s and 46 m^3/s, respectively. Between January 1970 and December 1979, monthly mean flows recorded at Lethbridge fell below 10 m^3/s eight times, indicating that the recommended minimum flow is difficult to maintain. These occurrences (six in summer months) suggest that daily flows of less than 10 m^3/s must have occurred frequently.

As a part of the PPWB Master Agreement on Apportionment (1969), Alberta is required to provide a share of the total natural flow of the South Saskatchewan River system to Saskatchewan. The contributions to this from each of the Red Deer, Bow, Oldman, and South Saskatchewan River basins can be established by Alberta. At present, there is no specified formula for this purpose. Alberta Environment is presently engaged in developing a framework plan for the South Saskatchewan River basin that could resolve this issue.

Except in very dry years, Alberta must maintain a minimum flow of 42.5 m^3/s at the Saskatchewan border. In years when one-half of the annual natural flow is less than 42.5 m^3/s, Alberta is entitled to a quantity of water equal to one-half the natural flow of the river. Therefore, if the province were to require that the Oldman River provide one-quarter of the minimum flow guaranteed Saskatchewan (42.5 m^3/s), then the 10 m^3/s minimum flow for protection of instream uses in the lower basin would also prove adequate for apportionment contributions. However, if greater than 25 percent is required from the Oldman River, then that minimum flow could be inadequate under some circumstances.

The description, thus far, has dealt with water supply at key points where irrigation diversions constitute the major demand, and has indicated flow criteria to protect instream uses and apportionment obligations. Present irrigation constraints and future irrigation demands in the irrigation districts have been reviewed.

To assess the complete present use situation, it is useful to summarize all withdrawals and consumptions for the basin and relate them to supply. A measure of supply to the basin can be taken from the computed natural annual flow at Lethbridge, 115 m^3/s (Table 23). For the lowest year on record, the annual mean was 45.5 m^3/s (1944). The longest prolonged dry period was 1937 to 1941, where the five-year annual mean was 78 m^3/s.

Natural flow calculations were not available for the recent low-flow year, 1977, for Lethbridge. However, a comparison of the difference between the recorded annual mean flow and the computed natural value for a previous relatively low-flow year (1973) suggests a natural annual mean flow for 1977 of 47.6 m^3/s. This value is comparable to the natural flow in 1944 (45.5 m^3/s), another very dry year.

TABLE 25. SUPPLY/DEMAND ANALYSIS - OLDMAN RIVER BASIN

COMPUTED NATURAL SUPPLY AT LETHBRIDGE (1912-75) - M^3/S

MEAN ANNUAL FLOW	115	
LOWEST ANNUAL FLOW	45.5	(1944)
LOWEST 5-YR ANNUAL FLOW	78	(1937-41)

CONSUMPTION IN A DRY YEAR M^3/S (BASED ON EQUIVALENT ANNUAL FLOW)	PRESENT	FUTURES		
		I	II	III
IRRIGATION	25	33	43	100
OTHER AGRICULTURE	0.6	0.6	0.6	—
MUNICIPAL	0.7	1.1	1.5	—
INDUSTRIAL	L 0.1	0.1	0.2	—
MINIMUM FLOW REQUIREMENTS M^3/S	10	10	10	10
TOTAL*:	36	45	55	100+

* DOES NOT INCLUDE RESERVOIR EVAPORATION LOSSES

NOTES:

I - ESTIMATED CONSUMPTION - 1990 (LITTLE EXPANSION OUTSIDE IRRIGATION DISTRICTS)

II - ESTIMATED CONSUMPTION WITH MAXIMUM USE OF AVAILABLE WATER FOR IRRIGATION (SHORTFALLS IN SOME YEARS) AND ECA (1979c) ESTIMATES OF WATER CONSUMPTION BY OTHER USES IN THE YEAR 2001

III - ESTIMATED CONSUMPTION BASED ON ESTIMATES OF AMOUNT OF IRRIGABLE LAND (NOT INCLUDING NEW DEVELOPMENT IN THE SOUTH SASKATCHEWAN RIVER BASIN THAT WOULD LOGICALLY BE SUPPLIED WITH WATER FROM THE OLDMAN BASIN)

L - LESS THAN

A basin-wide summary of uses is contained in Table 25. Included are estimates of present consumptions and a set of alternative foreseeable consumptions, for each use category. Also included are computed natural supply figures for Lethbridge.

The table includes information about water uses in agriculture other than irrigation. These uses, discussed in Chapter VIII.3, obtain water from sources other than the streams draining the basin. Water shortages and quality problems are widespread in this use category, especially in dry years.

It is clear from the totals in Table 25 that present water demands in the Oldman River basin place a strain on existing supplies in a dry year. Furthermore, if instream uses are to be protected, including a contribution to the water apportionment to Saskatchewan in the South Saskatchewan River, foreseeable potential increases in irrigation in this basin will be limited.

Future irrigation water requirements have been estimated for 1990 from projected acreages, using the same rate of water application per acre as at present. There is considerable uncertainty about whether any increased efficiencies of water delivery would be offset to some degree by increased water application per acre to reduce crop moisture deficiencies and to restore salt balance. The ECA has suggested that greatly increased efficiencies could result in a lower water withdrawal per acre irrigated. The Future II estimate in Table 25 assumes full usage of available water and it should be noted that this usage could not be achieved in a 1977-type year unless the ECA suggestion proved correct. The final column estimate is based on a very rough calculation of water needed to service the ultimate potentials suggested by Pedology Consultants and UMA. Clearly this estimate could not be accommodated by water from the Oldman River drainage.

Alternative measures that have been suggested as means to satisfy future uses in the Oldman River basin are summarized in the following. One of these requires major transfers of water from outside the Oldman River basin, and would naturally affect one or more other basins. For this reason, a summary of arguments in favour of and opposed to this type of measure has been presented separately (Chapter II.2).

Measure	Purpose	Comment
1. Improve existing irrigation facilities, including off-stream storage	increase irrigated acreage by 150,000 acres (60 000 ha)	Government of Alberta has committed over $200 million for this purpose
2. Onstream storage	firm up supply to LNID and increase irrigated acreage by another 150 000 acres (60 000 ha)	Government of Alberta has approved dam and other works

Measure	Purpose	Comment
3. Interbasin transfer	up to $55 m^3/s$ (SNBB, 1972)	no official proposal (see Chapter II.2)

In summary, the major consumptive use of water in the Oldman River basin is irrigation. This use is presently limited in dry years, but could be increased by more efficient use of available water. In order to achieve full potential irrigation use, by some estimates, additional water would be needed in the basin. By other estimates, (e.g., ECA, 1979c) the full reasonable potential for economically viable irrigation can be achieved by more efficient usage of existing waters. Greatly increased irrigation in this region could adversely affect water quality downstream.

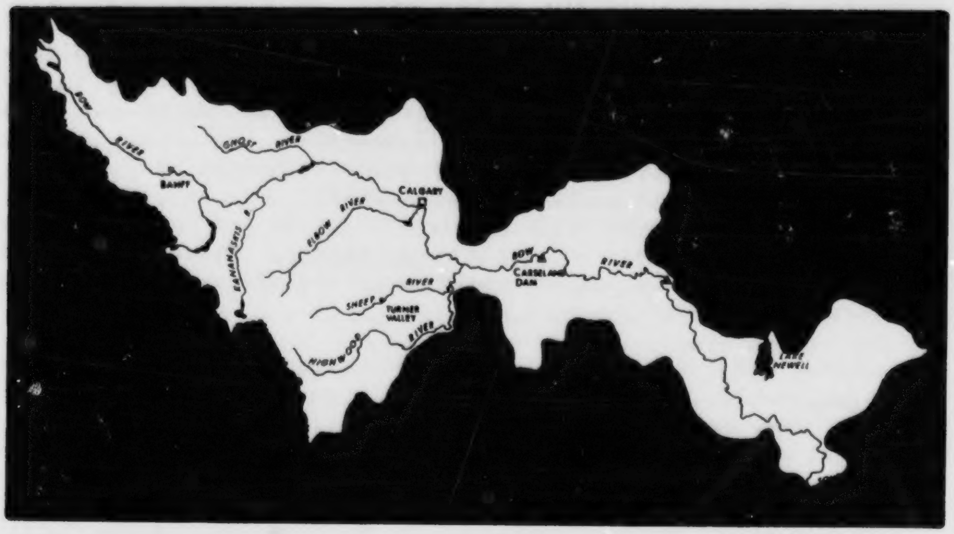
Municipal and industrial uses are relatively small and will remain small in comparison with irrigation use. Other agricultural uses are widespread and locally suffer both quantity and quality limitations. Particularly in upland areas, these problems are not easily solved.

Recreation uses in the basin include use of the "wild" upstream waters by those who value the natural environment for hunting, fishing, camping, and aesthetic purposes. Similar uses are made of the impoundments and regulated portions of the river farther downstream. Construction of a dam at or near the Three Rivers site is considered by some to threaten the natural flow and temperature conditions to the detriment of local recreation.

At present, many recreation and renewable resource uses are closely related to the artificial reservoirs. All commercial fishing, for example, is done in these water bodies. At the same time, the maintenance of a minimum flow in the Oldman River and major tributaries is considered to be necessary for fish survival as well as water quality control and assured municipal supply.

Although population increases will raise the level of recreation use in the central and lower portions of the basin, existing developments have already defined most limitations for recreational opportunities. Future increased irrigation development would primarily increase conflict by way of influence on minimum flow values, unless these are established and guaranteed by regulatory authorities.

Figure 40. THE BOW RIVER BASIN.

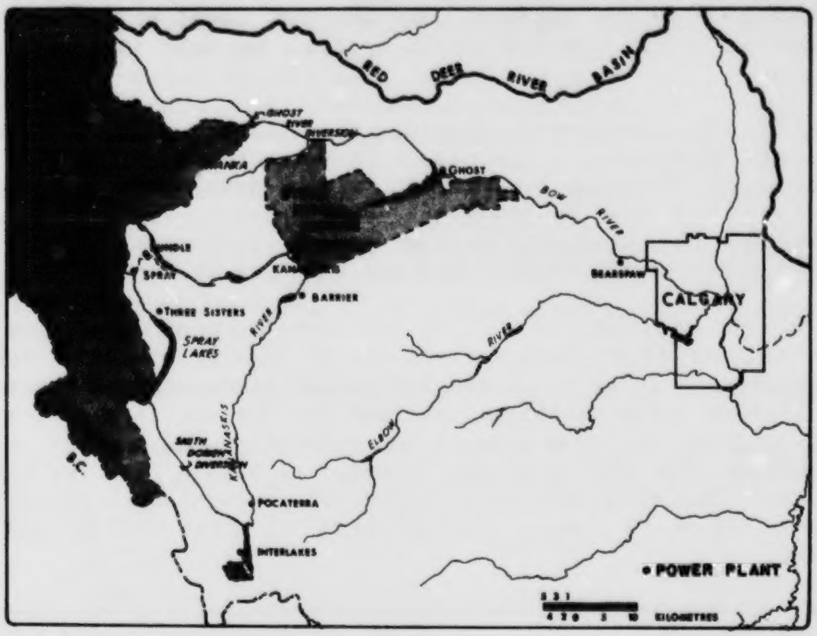

BOW RIVER
GHOST RIVER
BANFF
CALGARY
ELBOW RIVER
KANANASKIS R
SHEEP RIVER
TURNER VALLEY
HIGHWOOD RIVER
BOW
CARSELAND DAM
RIVER
LAKE NEWELL

3. BOW RIVER BASIN

The Bow River drainage basin (Figure 40) is the smallest of those considered in this report. The river rises high in the glacier-fed lakes of Banff National Park, north of Lake Louise. It passes southeastward through Banff, then eastward through Calgary, and eventually joins the Oldman River to form the South Saskatchewan River. In total, the Bow River drains an area of 25 000 km^2. Downstream from Banff all recorded flows are considered to be "regulated".

Several tributaries of the Bow River above Calgary, including the Cascade, Spray, Kananaskis, and Ghost Rivers, have been developed for hydro power purposes. The dams and diversions of this development are illustrated in Figure 41 (see also Chapter VIII.6). Total power production capacity of these hydro plants, plus those on the Bow River itself, total 325 MW.

Figure 41. HYDRO POWER DEVELOPMENT IN THE BOW RIVER BASIN.


RED DEER RIVER BASIN
GHOST RIVER DIVERSION
ANKA
GHOST
BOW RIVER
NDLE
SPRAY
KANA
BARRIER
BEARSPAW
CALGARY
THREE SISTERS
SPRAY LAKES
KANANASKIS RIVER
SMITH DORRIEN DIVERSION
POCATERRA
INTERLAKES
ELBOW RIVER
B.C.
• POWER PLANT
5 3 1
4 2 0 5 10 KILOMETRES

In this part of the basin, the major use of water is for recreation and related aspects of environmental stewardship, although some industrial uses are present. Some of the industrial water requirements (e.g., for cement production) are supplied by ground water. Along the Bow River downstream from Banff National Park, and along the Elbow River, several native communities use the waters for domestic and cultural purposes.

Approximately half the surface area of Banff National Park lies in the Bow River basin. Other recreation and wilderness areas include: Bow Valley, Bragg Creek, and Big Hills Springs Provincial Parks; the Ghost River Wilderness Area; and the recently developed Kananaskis Provincial Park and the Kananaskis Country recreation area. These lands provide varying degrees of protection of water quality and opportunity for the public to enjoy the water resources.

Existing uses and both the present and the foreseeable recreation activities can also affect environmental conditions. In Banff National Park, Parks Canada is concerned about fish disease; effects of stream manipulation on erosion, fish habitat and water quality; water supply for domestic use; and the effects of sewage on water quality. For example, local pollution due to sewage effluent from recreation centres has been identified as a problem.

The large Kananaskis development southeast of Banff Park may generate a dramatic increase in recreational activities in a large area of this basin. This new development, as well as expansion of use in the established centres, will increase the potential for degradation of water resources unless strict control measures are established and enforced by the Province.

River regulation for hydro development can result in substantial short term variability of flow in the Bow River and tributaries. In 1979, on the Kananaskis River below Barrier Dam, the highest daily discharge recorded for the entire year was 28.8 m^3/s on May 19. Just four days later, the lowest daily discharge for the year was recorded at 0.14 m^3/s. The Alberta Fish and Game Association has expressed concern about the effects of this type of rapid variability in flow on fish and fish habitat.

TABLE 26. FLOW STATISTICS (M^3/S) FOR SELECTED POINTS - BOW RIVER
(EC, 1980A; WER, 1980A)

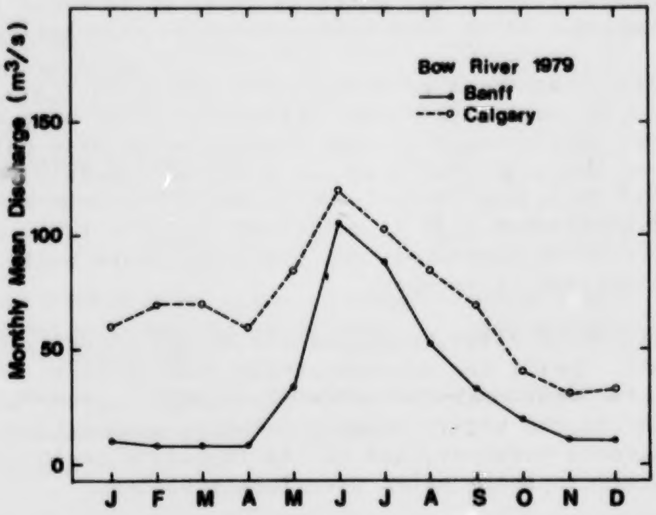
RIVER -	HYDROMETRIC STATION (PERIOD OF RECORD)	MEAN ANNUAL	LOWEST ANNUAL	HIGHEST ANNUAL	LOWEST MONTHLY	HIGHEST MONTHLY	MIN. 5-YR MEAN	MAX. 5-YR MEAN
BOW	BANFF [1] (1911-79)	40.0	28.0 (1949)	51.1 (1928)	5.4 (FEB/37)	210 (JUNE/72)		
	CALGARY [2] (1912-79*)	92.1	58.4 (1941)	147 (1916)	18.9 (MAR/23)	472 (JUNE/23)		
	BASSANO DAM [3] (1912-75)	127.8	75.6 (1949)	232 (1916)	10.8 (DEC/36)	887 (JUNE/23)	94.4 (1937-41)	172.5 (1913-17)
	NEAR MOUTH [2] (1965-79)	102	44.0 (1977)	146 (1965)	21.8 (SEPT/79)	591 (JUNE/67)		

1. RECORDED FLOWS - NATURAL
2. RECORDED FLOWS - REGULATED
3. COMPUTED FLOWS - NATURAL

* DISCONTINUOUS RECORD

Statistics of flow for selected points in the basin are contained in Table 26. The mean annual flow at Banff is 40 m^3/s, which is about one-third the computed natural flow below Bassano Dam, in the lower part of the basin. The effects of regulation below Banff are illustrated in Figure 42, which compares the greater seasonal variation at Banff with the more even distribution downstream at Calgary, particularly in winter months. The upstream works not only serve to produce power, but also increase the base flow in the river, which is considered to be beneficial in lower portions of the basin. The increase in base flow occurs in winter months when power generation is greatest. Daily fluctuations in power production continue to cause short-term discharge fluctuations immediately downstream of the power plants.

Figure 42. COMPARISON OF BOW RIVER FLOWS AT BANFF AND CALGARY.



The major municipal use in the basin is at Calgary. As compared to Edmonton, there is relatively little industrial demand for water in Calgary. Future requirements can be related to projected population growth and the expansion of water supply and sewage facilities to include neighbouring municipalities. Present and projected (2006) withdrawals are about 5 m^3/s and 12.5 m^3/s, respectively. Net consumption is estimated to be just under 25 percent.

The mean annual recorded flow of the Bow River at Calgary is about 90 m^3/s, while the lowest recorded monthly mean is about 20 m^3/s (March, 1923). The Elbow River, presently the most important source of water for Calgary, is regulated and has an observed mean annual flow of just under 10 m^3/s. In the future, water will be increasingly withdrawn from the Bow River, and Calgary is not expected to suffer water shortage in the foreseeable future.

Present water use by Calgary, however, results in a significant contamination of the river downstream. This has particularly affected fish populations during warm, low-flow periods. Concern about this type of problem has resulted in plans for expanded and upgraded sewage treatment facilities. Tertiary treatment facilities are expected to be in operation by 1983. Similar though more localized concerns exist for other municipalities in the basin. Considering the size of the river, the present and projected increases in its adjacent populations, and the importance of its instream uses, it is clear that water quality management is an important concern in this basin.

Flooding can be a problem in the foothills region, down to Calgary. Although upstream reservoirs offer some measure of protection, their small storage capacities provide only limited suppression during the peak of extreme floods. Flood-prone portions of Calgary have been identified and zoned by the provincial government. It is estimated that the flood that could be statistically expected once every 100 years could result in millions of dollars in damages.

The Highwood River, supplemented by its major tributary the Sheep River, joins the Bow downstream from Calgary. Recreation and wildlife sanctuary areas in Kananaskis Country along these rivers exist in the higher reaches. Native communities use water for subsistence purposes, and in the foothills region, extensive gas and oil developments exist near Turner Valley.

Small diversions, primarily for stock watering, exist between the Highwood River and the Little Bow River, but there are no formal irrigation districts in this part of the Bow River drainage. Municipal and industrial water uses are small (some are from ground water). No serious constraints are noted, although well water requires treatment in some places, and local stock watering supplies are limited.

Downstream of Calgary on the Bow River, the major consumptive use of water is for irrigation (Chapter VIII.2). The total water consumption in the recent dry year of 1977 for the three irrigation districts and private irrigation was over one million dam^3 (equivalent to 31 m^3/s). A summary of all water uses is contained in Table 27.

TABLE 27. SUPPLY/DEMAND ANALYSIS - BOW RIVER BASIN

COMPUTED NATURAL SUPPLY BELOW BASSANO DAM (1912-75) - M^3/S	
MEAN ANNUAL FLOW	127.8
LOWEST ANNUAL FLOW	75.6 (1949)
LOWEST 5-YR ANNUAL MEAN	94.4 (1937-41)

CONSUMPTION IN A DRY YEAR M^3/S (BASED UPON EQUIVALENT ANNUAL FLOW)	PRESENT	FUTURES *		
		I	II	III
IRRIGATION	31.0	38.0	65.0	165
OTHER AGRICULTURE	0.2	0.2	0.3	—
MUNICIPAL	1.3	1.6	3	—
INDUSTRIAL	L 0.1	0.1	0.1	—
NET TRANSFER TO OTHER BASINS	4.5	5**	9**	—
CONTRIBUTION TO APPORTIONMENT	38.0	38.0	38.0	38
TOTAL***	75.0	83.0	115.4	203+

* THE THREE CATEGORIES ARE AS FOLLOWS: I - ESTIMATED CONSUMPTION TO 1985; II - ASSUMES MAXIMUM BASED UPON EXISTING DEMANDS; III - BASED ON HIGHEST ESTIMATE OF IRRIGABLE LAND

** HIGHLY SPECULATIVE - PROPORTIONAL TO INCREASES IN IRRIGATION CONSUMPTION

*** DOES NOT INCLUDE RESERVOIR EVAPORATION LOSSES

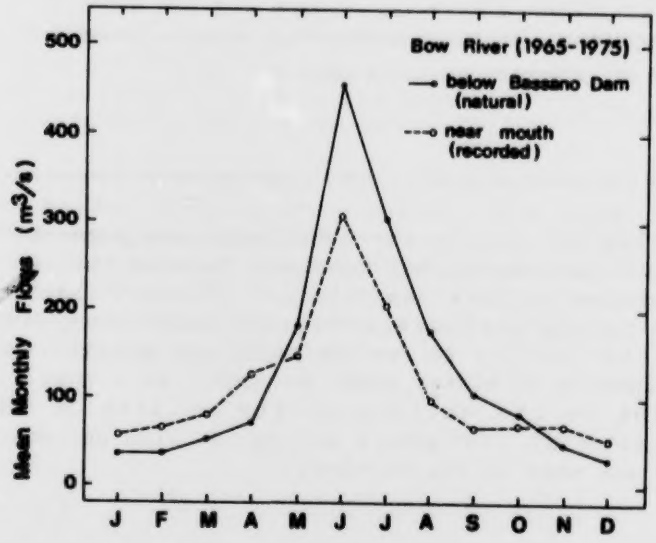
L = LESS THAN

Regulation of the river for hydro can augment flows during the irrigation season, but conflicts between the two user groups arise. Water allocation policy in Alberta (Chapter I.7) gives priority to agriculture over power production, but there is a need by the utility to restore reservoir supplies in the autumn in anticipation of winter power demands. As a result, there is a limitation on the ability of the utility to fully meet the expectations of irrigators during low flow periods. Allocation decisions are made by the province.

At present the Western Irrigation District, supplied by a diversion in Calgary, is constrained during low-flow years, due primarily to a lack of adequate storage and canal works. A similar problem exists for the Bow River Irrigation District, for which water is diverted near Carseland Dam (Figure 40). The main concern is the low capacity of the canal from the Bow River to Lake McGregor. Due to internal storage capacities, irrigation is not presently constrained in the Eastern Irrigation District, which is supplied by a diversion at the Bassano Dam. Storage is above only about two-thirds of that district, however, so that expansion is limited. Some return flow from the irrigation districts is channelled to the Red Deer and Oldman Rivers. A summary of these losses to the basin is included in Table 27.

Estimates of future irrigation expansion in these districts are described in Chapter VIII.2. Future water requirements are summarized in Table 27. It appears that total irrigable areas exceed the lands that could be supplied by available water, even with improved storage and conveyance works. In 1981, the Government of Alberta announced the allocation of $334 million for such improvements in southern Alberta, a portion of which will be used in this basin. The availability of water for irrigation could be influenced by decisions made regarding the contributions of the Bow River to the apportionment requirements for the South Saskatchewan River, as discussed in the preceding section.

Figure 43. COMPARISON OF NATURAL AND RECORDED FLOWS IN THE LOWER BOW RIVER BASIN.



In the region between Bassano Dam and the mouth, there is little natural surface drainage to the Bow River, though there are irrigation return flows. The pattern of natural flow computed at Bassano Dam is compared to the pattern of observed flow at the mouth in Figure 43. This again illustrates the smoothing effects of upstream regulation, and shows the seasonal variation in streamflow in this part of the basin.

In this stretch of the Bow River, upstream diversions can result in very low flows in the summer months of dry years. Paetz (1981) has described flows of less than five m^3/s which have resulted in fish die-offs. No specific minimum flow requirements have been established for the protection of fish in this river.

Natural supply to the basin in a low flow year (such as 1949) is about 76 m^3/s at Bassano Dam (Table 26). In 1977, a more recent very dry year, the observed mean annual flow at the mouth of the Bow was 44 m^3/s. If these two years are assumed to be comparable in representing dry conditions, these figures suggest a consumptive use of 40-50 percent. This estimate is consistent with a total estimated consumptive use for the basin of about 37 m^3/s (Table 27). In the table, the contribution to apportionment of 38 m^3/s has been included on the assumption that one-half the natural flow of the Bow River would be required for that purpose. That value is probably an upper limit. Alberta Environment is presently studying the likely future contributions for apportionment from each of the Red Deer, Bow, and Oldman Rivers. The estimated present consumption plus the 38 m^3/s totals about 75 m^3/s, which is close to the natural supply in a low-flow year.

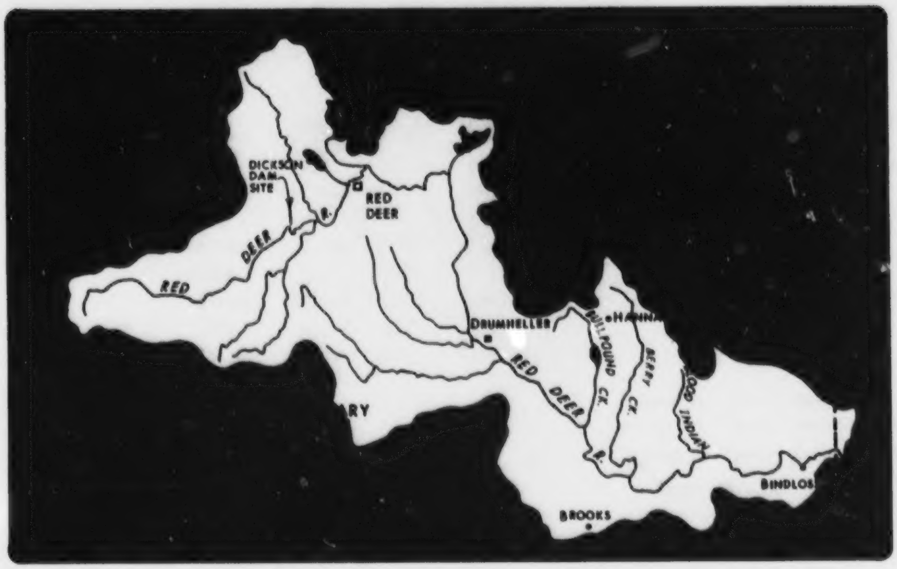
The derivations of near-and far-future demands in Table 27 are explained in Chapter VIII.2. It is clear that even near-future water requirements for irrigation (38 m^3/s) could not be met in a series of a few dry years if half the Bow River flow were allocated to apportionment. It is also clear that all other uses have a minor impact compared with irrigation. Two potential thermal power plant sites have been identified near Bassano Dam. Frey (1981) suggests that plants at these locations could require a significant portion of the river flow during a low-flow period. However no specific proposal for these developments has been made.

In summary, the Bow River basin presently has inadequate storage and conveyance works to accommodate its largest consumptive user, irrigation. Furthermore, total irrigable acreages are unlikely to be supplied due to insufficient water in the basin. The SNBB (1972) described a possibility for importation of about 115 m^3/s to the Bow River from northern basins, half of which could be diverted to the Oldman River. The Alberta government appears to be opposed to this type of transfer.

Except for problems related to regulation for hydro development, recreation in the upper reaches can continue to enjoy adequate supplies of water and, with proper management, water of suitable quality. Large municipal requirements can be met, although serious water quality problems will continue and will deteriorate without proper controls. Low-flow conditions in warm summer months can cause fish die-offs in the lower reaches of the river.

Stock watering and local domestic farm uses suffer from local quantity and quality problems, as in most portions of the prairie provinces. Water requirements for renewable resource uses are small and are not likely to experience limitations.

Figure 44. THE RED DEER RIVER BASIN.


DICKSON DAM SITE
R.
RED DEER
RED
DEER
DRUMHELLER
HANNA
BULLPOUND CK.
BERRY CK.
RED
DEER
R.
OOD INDIAN
ARY
BINDLOS
BROOKS

4. RED DEER RIVER BASIN

The Red Deer River (Figure 44) rises in the Rocky Mountains, entering the foothills region through a pass in the Vermillion Range. Several major tributaries join the river prior to its passage through Red Deer. East of Red Deer, it bends southeastward, passing through Drumheller. North of Brooks, the river continues eastward to its confluence with the South Saskatchewan River, just inside the province of Saskatchewan.

No major regulation yet exists on the Red Deer River, although there are small holding dams on some tributaries in the lower basin. These, as well as the effects of flows it receives from irrigation districts in the Bow River basin, have altered the natural flow in the lower basin. Thus, while streamflow as far downstream as Drumheller is considered to be "natural", flows recorded near the mouth at Bindloss and Empress are termed "regulated".

TABLE 28. FLOW STATISTICS (m^3/s) FOR SELECTED POINTS - RED DEER RIVER
(EC, 1980A; MER, 1980A)

RIVER -	HYDROMETRIC STATION (PERIOD OF RECORD)	MEAN ANNUAL	LOWEST ANNUAL	HIGHEST ANNUAL	LOWEST MONTHLY	HIGHEST MONTHLY	MIN. 5-YR MEAN	MAX. 5-YR MEAN
RED DEER -	RED DEER[1] (1912-79*)	49.1	20.9 (1949)	125 (1915)	2.8 (DEC/36)	474 (JULY/15)		
-	DRUMHELLER[1] (1916-79*)	54.9	28.9 (1961)	146 (1916)	2.2 (DEC/22)	405 (JUNE/28)		
-	BINDLOSS[2] (1961-79)	58.6	31.4 (1979)	119 (1965)	3.2 (JAN/63)	352 (JULY/65)		
-	BINDLOSS[3] (1912-75)	61.9	26.0 (1941)	158 (1915)	1.0 (FEB/22)	703 (JULY/15)	36.6 (1937-41)	102.5 (1913-17)

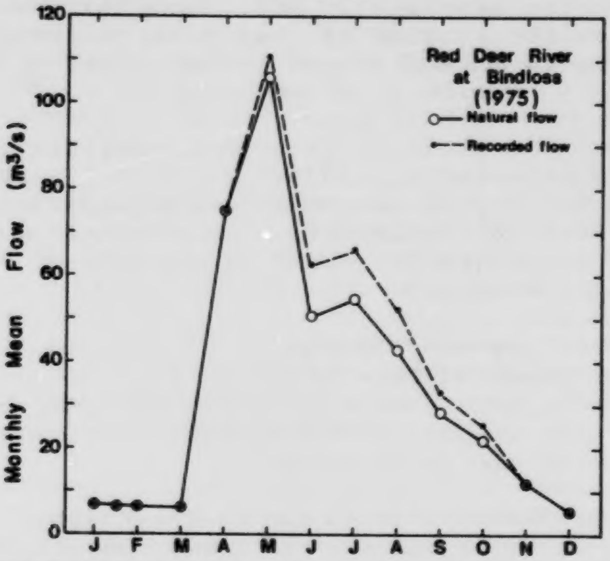
1. RECORDED FLOWS - NATURAL
2. RECORDED FLOWS - REGULATED
3. COMPUTED FLOWS - NATURAL

* DISCONTINUOUS RECORD

River flow in this basin is lowest during winter months, when it is variable and affected by ice build up and replenishment of ground water systems. The effects of snowmelt and spring rains dramatically increase flows in the early summer months. Statistics of flow at key locations are contained in Table 28. The computed natural flow data for the river at Bindloss represent a measure of supply to the basin as whole. The seasonal differences between computed natural and actual recorded monthly means at Bindloss for the fairly low flow year of 1975 are indicated in Figure 45. The higher recorded flows reflect, in part, the return flows from the irrigation districts supplied by the Bow River.

The long-term variability of flow in the Red Deer River is demonstrated by the 5-year moving mean data in Table 28. The period 1937-1941 was the driest (about 37 m^3/s), whereas the largest value was for the period 1913-1917 (about 105 m^3/s). The early 1950s was also a period of relatively high flow for this basin, while the late 1970s were dry years.

Figure 45. **COMPARISON OF NATURAL AND RECORDED FLOWS IN THE LOWER RED DEER RIVER.**



The uppermost reaches of this basin include portions of Banff National Park, and mountain and foothill terrain which is heavily populated by a variety of game animals. In the lower foothills and somewhat downstream, the river and its tributaries are good habitat for game fish. Whitewater canoeing is an additional recreational pursuit in the wilder upstream reaches. Municipal and industrial demands here are very small and are not expected to develop to an extent where water supply would become an issue. Forestry, mining, and petroleum operations do not significantly affect the river in this portion.

Irrigation and other agricultural uses in the upper part of the basin also are not significant insofar as water supply and quality are concerned. There is, however, some flooding of agricultural land upstream of Red Deer.

The city of Red Deer is a rapid growth urban centre whose demands for water for municipal and local industrial requirements are increasing. At present there is sufficient water supply to meet the local needs at Red Deer (less than 0.2 m^3/s), although winter flows can become very low (e.g., less than 2.8 m^3/s in December, 1936).

New major petrochemical plants near Red Deer could be the forerunners of additional resource-based industrial development. In addressing these possible future events and the uses of water in the lower reaches, the Alberta Environment Conservation Authority (AECA) reviewed planning studies by Alberta Environment and held public hearings in 1977. Among the several concerns reviewed was the possibility of up to six petrochemical plants requiring up to 0.6 m^3/s flow of process water, in the vicinity of Red Deer.

A body of opinion exists which opposes industrial development here (AECA, 1977). Extensive population and industrial development could not only severely strain natural local supplies, but could also cause additional degradation of downstream water quality, which is presently very poor due to periodic oxygen deficiencies.

Industrial demands for water throughout the basin are described in Chapter VIII.4. At present there are no significant industrial uses, other than at Red Deer. The AECA, however, also considered the possibility of future coal developments, and the industrial use of coal in the basin.

One such development is the Sheerness thermal power plant now under construction southeast of Hanna. Two 375 MW units have been approved which will require about 21 000 dam^3 per year, or about 0.7 m^3/s, piped from the Red Deer River. Return flow (about 50 percent) will be via Berry Creek and will be largely consumed for irrigation in that basin. The AECA estimated a continuous water demand of about 4.2 m^3/s with the full development of four 1000 MW plants and other coal-related industries in the future. Alberta Environment (1975) estimated ranges of water consumption for all industrial, municipal, and thermal power developments of 1.8 - 3.0 m^3/s, for 1984 and 3.0 - 6.5 m^3/s, for 2004.

Agriculture in the central and lower portions of the basin uses small amounts of water, though local shortages occur in dry years due to inadequate dugout capacities. Local water quality problems due to dugout and well contamination can be serious. Water for irrigation is drawn from the Red Deer River and some of its tributaries. The Deadfish Diversion from the Red Deer River to the Berry Creek basin will be completed in 1983 and will support further irrigation there. Agriculture is also blamed for some of the water quality problems in the Red Deer River.

Expansion of irrigation in the Red Deer River basin is a controversial subject. The Special Areas portion north of the river downstream of Drumheller (Chapter VIII.2) is considered by some to be generally unsuited for expansion because of soil salinity and terrain problems (Pettapiece and Kjearsgaard, 1980).

Others are unconvinced and suggest that major irrigation development is feasible.

Estimates of potential irrigation expansion (given sufficient water) has been made by Pedology Consultants (1980) and UMA (1981). Pedology Consultants estimated a total of about 1,650,000 acres (670 000 ha) in the Red Deer River basin outside existing irrigation districts considered to be developable for irrigation. Of this, 1,250,000 acres are in low need areas (based on climate), while the balance is in moderate need areas. None were considered to be of high need, based on the climate. UMA estimated a total of 1,500,000 irrigable acres (600 000 ha), which reduced to about 46,000 acres if areas with poor ratios of cost to benefit and with a relatively low need for water were eliminated. It should be noted that in both reports some land identified could possibly be supplied from the Bow River. Supplies of water available in this basin would not be sufficient to support major irrigation expansions.

The recommendation by the AECA, after considering present and foreseeable water requirements, was essentially that development should be planned to suit the present capacity of the river, and that measures were required to provide offstream storage to improve efficiencies. It recommended steps to resolve water quality problems at the source, rather than by dilution. It also recommended against instream water storage as a measure to improve supply and quality.

Nevertheless, based on an analysis by Alberta Environment of several potential damsites, the province in 1978 approved construction of the Dickson Dam, just upstream of Red Deer, to be in operation by 1983. The dam was chosen as the method to ensure supply to downstream users.

The effects of the dam include the flooding of 4420 acres (1790 ha) by a reservoir with a storage capacity of 190 000 dam^3. There will also be a decrease in the annual peak flows and an increase in low flows downstream. Site selection was based in part on a desire to provide effective flood control and to ensure a minimum flow of about 16 m^3/s immediately downstream.

The Dickson Dam will also provide opportunity for construction of a 20 MW hydro power facility at the site. Efforts will be made to ensure that the power facility will not in itself result in adverse environmental effects (Simpson and Sengupta, 1981).

Alberta Environment (1975) examined minimum flow needs . downstream from the dam. value of just over 15 m^3/s was considered necessary to protect water quality and fish habitat. Added to that were two estimates for consumptive uses by the year 2004: 3 m^3/s for minimum industrial growth, and about 6.5 m^3/s for maximum industrial growth. Clearly, the Dickson Dam will not enable a guaranteed minimum flow in winter months to meet either of these possibilities, if it will only guarantee 16 m^3/s and if a minimum flow of 15 m^3/s is observed. Alternative measures, such as offstream storage or aeration of waters in stretches where low flows could affect water quality, are possible. The Alberta Environment estimates did not include provision for any irrigation consumption.

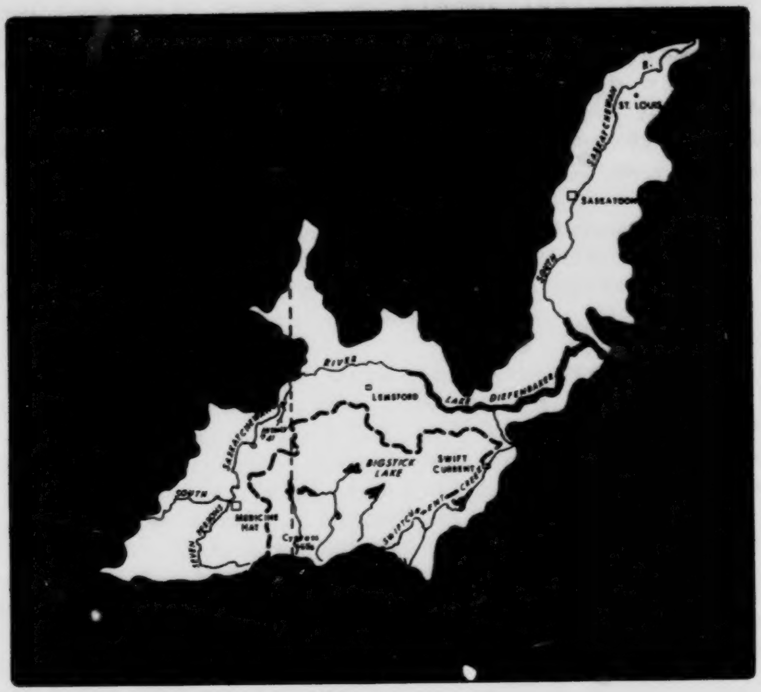
Agricultural use of water is not expected to increase substantially unless major irrigation development occurs. Regulation of the river will not significantly increase the potential for irrigation, in part because of poor opportunities, and in part because supplies will not be sufficient for major expansion. Water works in support of the Sheerness plant and the Deadfish Diversion are expected to support irrigation of about 20,000 acres by 1986. Estimates of the potential for major irrigation expansion indicate that the needs and benefits are less than in other parts of southern Alberta. Furthermore, large developments could not be adequately supplied with water from the Red Deer River basin.

Because there is little consumptive use of water, a high fraction of the flow of the Red Deer River contributes to Saskatchewan's apportioned share of the South Saskatchewan River drainage. Decisions made by Alberta as to how this contribution should change in the future will influence the development of high consumption water usage in the basin.

In summary, increased industrial and thermal power developments, either under construction or foreseen, will place increased demands on water supply. In the upper reaches, developments are not expected to impair present recreational uses. The new dam will affect fish migration, but Alberta Environment feels that it will be far enough downstream that game fish populations in the upper reaches will not be affected. Recreational use of the central and lower reaches will continue to increase, though sports fishing and canoeing might suffer as a result of the dam. The water available in this basin is not sufficient to permit a major expansion in irrigation.

The SNBB (1972) has described two possible diversions from northern basins for importation of water to the Red Deer River basin. One could supply about 115 m^3/s from the North Saskatchewan, all of which could be passed to the Bow River basin. The other could supply 170 m^3/s from the North Saskatchewan via the Battle River. As mentioned earlier, the Alberta government appears to be opposed to transfers of these types.

Figure 46. THE SOUTH SASKATCHEWAN RIVER BASIN.


R.
ST. LOUIS
SASKATCHEWAN
SASKATOON
SOUTH
RIVER
LEMSFORD
LAKE DIEFENBAKER
SASKATCHEWAN
SOUTH
BIGSTICK LAKE
SWIFT CURRENT
SWIFTCURRENT CREEK
MEDICINE HAT
SEVEN PERSONS
Cypress Hills

5. SOUTH SASKATCHEWAN RIVER BASIN

The South Saskatchewan River basin (Figure 46) begins at the junction of the Oldman and Bow Rivers. It includes an area of southeastern Alberta, centred around Medicine Hat, and an elongated portion of western Saskatchewan. The river joins the North Saskatchewan River east of Prince Albert.

Major tributaries include the Red Deer River and Swiftcurrent Creek. The latter flows into the upper end of Lake Diefenbaker, a reservoir established in 1967 by construction of the Gardiner and Qu'Appelle River Dams. The total area drained in the basin is 35 000 km^2, bringing the total drainage area of the system, including upstream basins, to over 150 000 km^2.

Included in the discussion of this basin is information concerning the Cypress Hills North Slope, an adjacent 14 000 km^2 closed drainage area.

At the upstream end, supply to the South Saskatchewan River basin can be greatly reduced by uses in the Oldman and Bow Rivers. The major consumptive use of water in the Alberta portion of this basin is irrigation, which consumes about 1 m^3/s. Irrigation in tributary areas is constrained in dry years. The main stem of the river receives the effluent from upstream irrigation diversions and other uses, so that water quality could become a future constraint.

The city of Medicine Hat withdraws water for both its domestic and some industrial needs, as well as for its thermal power plant. In low-flow years, water supply is adequate, but not excessive. The city, and local industries requiring water for their own intakes, however, are concerned about future supply, depending upon the volumes allocated from this river in the apportionment provisions (see next paragraph). At present, total withdrawals by Medicine Hat amount to about 0.4 m^3/s, about one-half of which is consumed.

Farther downstream, just into Saskatchewan, the Red Deer River contributes water that will increasingly be subject to the effects of a variety of uses. At this point in the basin, however, there is an obligation by Alberta to supply an apportioned quantity of water to Saskatchewan. This amounts to at least 42.5 m^3/s at any time except in very dry years, when it would amount to one-half the natural flow in Alberta. A study presently underway by Alberta Environment is designed to aid in the development of a policy regarding the relative allocations of this apportioned requirement among the three major tributaries. The PPWB has reviewed the effects of changing the annual accounting for the apportionment to a shorter period and has concluded that there is no need to change the annual accounting period. Both Alberta Environment and the ECA appear to be opposed to such a change.

The PPWB monitors water quality at two locations near the Saskatchewan border, one on the Red Deer River and one on the South Saskatchewan River in Alberta. A summary of this information, including cases where specific objectives have been exceeded, is produced by the PPWB (1981). A high number of "excedences" have occurred for total copper, manganese, nitrogen, phenols, and total phosphate in the Red Deer River. In addition, 22 percent of samples between 1974 and 1981 exceeded the dissolved oxygen objective for that river. For the South Saskatchewan River, a high percentage of "exceedences" for iron, manganese, nitrogen, phenols, and total phosphorous have been noted.

Between the Red Deer River and Lake Diefenbaker, agricultural uses predominate. Lands irrigated are poorly drained and soil salinity is a problem. Ground water is often too saline for use in irrigation. Any significant expansion of irrigation of salinized lands, together with increased usage of anhydrous ammonia fertilizer, could further impair the quality of water used for irrigation (Fitzgibbon, 1981). Local water quality and quantity problems significantly affect stock watering and domestic farm uses.

Agriculture is also the prime water use industry in the several closed drainage basins which make up the nearby Cypress Hills North Slope area. Water supply is not large and quality problems can be locally severe due to the lack of drainage to outside basins. Present irrigation and other agricultural uses are at or near the maximum possible, with available water. In the Bigstick Lake basin, Saskatchewan Environment has even suggested some reduction in private use in tributary areas.

Water flow records for the South Saskatchewan River between Alberta and Lake Diefenbaker are available from a location near Lemsford. Computed annual natural flow statistics are contained in Table 29, as well as more recent recorded flow information, for a limited period. No water flow measurements have been made at this location since 1970. The PPWB uses the combined flows recorded at locations in the lower parts of the Red Deer (Bindloss) and South Saskatchewan (Highway 41) Rivers basins to determine supply to Saskatchewan.

If the lowest computed annual natural flow at Lemsford (167 m^3/s) represents the natural supply originating in Alberta in a dry year, then one-half that amount (about 80 m^3/s) would be guaranteed to Saskatchewan. The latter could also be assumed to be a rough approximation of the supply to Lake Diefenbaker in a dry year since the net effect of small tributary inflows, water use, and evaporation between Lemsford and the lake would be small. The actual difference between the natural flow at Lemsford and the combined recorded flows of the Red Deer and South Saskatchewan Rivers near the Alberta boundary for the period 1967-75 averaged about 50 m^3/s.

TABLE 29. NATURAL AND RECORDED FLOWS (m^3/s)
SOUTH SASKATCHEWAN RIVER NEAR LEMSFORD
(EC, 1980a; WER, 1980a)

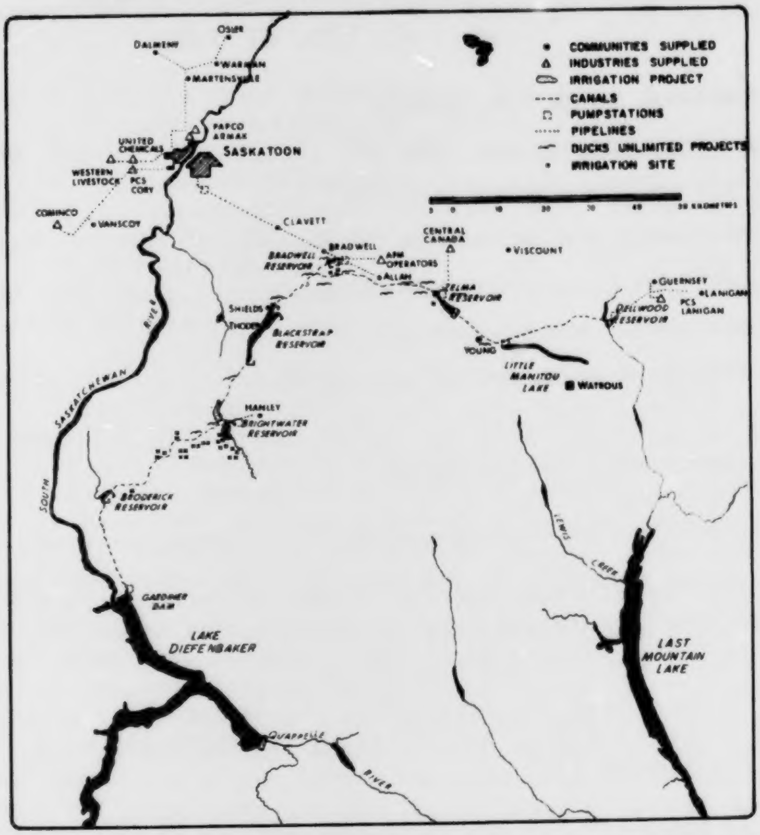
MEAN ANNUAL NATURAL FLOW (1912-75)	300
MEAN ANNUAL RECORDED FLOW (1959-70)*	256
LOWEST ANNUAL MEAN NATURAL FLOW (1941)	167
LOWEST ANNUAL MEAN RECORDED FLOW (1962)	181
HIGHEST ANNUAL MEAN NATURAL FLOW (1916)	517
LOWEST MONTHLY MEAN FLOW (NATURAL) (2/37)	24
LOWEST 5-YEAR ANNUAL MEAN (NATURAL) (37-41)	207

* ONLY PERIOD OF RECORD AVAILABLE

The live storage capacity of Lake Diefenbaker is about four million dam^3, although total storage is over twice that amount. The reservoir is designed for multiple uses including power generation, irrigation, industrial, municipal, and recreation uses. Some users are supplied by the Saskatoon-Southeast Water Supply (SSEWS) canal and others by diversion to the Qu'Appelle River (see Chapter II.2).

A canal from the East Side Pump Station of the Gardiner Dam takes water northward along the east side of the river to Broderick Reservoir (Figure 47). Between the canal and the river, and northward, the South Saskatchewan River Irrigation District (SSRID) diverts water for irrigation. From Broderick Reservoir, the SSEWS canal delivers water northeastward to other reservoirs and pipelines. Additional irrigation diversions occur along the SSEWS canal. The Saskatchewan Water Supply Board is responsible for the works along the SSEWS canal, supplying Saskatchewan Departments of Agriculture, and Tourism and Renewable Resources, as well as industrial and municipal users supplied by pipeline.

Figure 47. THE SASKATOON SOUTH EAST WATER SUPPLY (SSEWS) SYSTEM. (DREE and Saskatchewan Environment).


COMMUNITIES SUPPLIED
INDUSTRIES SUPPLIED
IRRIGATION PROJECT
CANALS
PUMPSTATIONS
PIPELINES
DUCKS UNLIMITED PROJECTS
IRRIGATION SITE
0 10 20 30 40 50 KILOMETRES
OSLER
DALMENY
WARMAN
MARTENSVILLE
PAPCO
ARMAX
UNITED CHEMICALS
SASKATOON
WESTERN LIVESTOCK
PCS CORY
COMINCO
VANSCOY
CLAVETT
CENTRAL CANADA
VISCOUNT
BRADWELL
BRADWELL RESERVOIR
AMK OPERATORS
ALLAN
ZELMA RESERVOIR
GUERNSEY
LANIGAN
PCS LANIGAN
DELLWOOD RESERVOIR
SHIELDS
THODE
BLACKSTRAP RESERVOIR
YOUNG
LITTLE MANITOU LAKE
WATROUS
HANLEY
BRIGHTWATER RESERVOIR
BRODERICK RESERVOIR
SOUTH SASKATCHEWAN RIVER
GARDINER DAM
LAKE DIEFENBAKER
LEWIS CREEK
LAST MOUNTAIN LAKE
QU'APPELLE RIVER

Total water supply in 1980 from the canal leaving the Gardiner Dam is described in Table 30. An increase from the present average over the year of 3.5 m^3/s to 5.2 m^3/s in the foreseeable future has been estimated from discussion with SWSB and SSRID staff.

The major potential expansion at this point is related to the once-estimated irrigation development of about 650,000 acres (260 000 ha) from Lake Diefenbaker. This estimate has been successively reduced to 450,000, then 290,000 acres. At present, the east side SSRID irrigation serves about 31,000 acres (12 500 ha), with an estimated future increase to about 45,000 acres (although 60,000 acres is considered to be the maximum develop-

TABLE 30. WATER DIVERTED FROM GARDINER DAM EAST SIDE PUMP PLANT (M^3/s) - 1980
(SASKATCHEWAN WATER SUPPLY BOARD, 1981; SSRID, 1981)

TOTAL PUMPED	3.5		
SSRIP		2.6	
- IRRIGATION CONSUMPTION			1.7
- LOSSES			.4
- RETURN TO S.S. RIVER			.5
			2.6
SSEWS (WATER SUPPLY BOARD)		0.9	
- INDUSTRY, MUNICIPALITIES			0.1
- IRRIGATION			0.4
- RECREATION			0.2
- WILDLIFE			0.2
			0.9
	3.5	3.5	3.5

able). The SSEWS canal serves an additional 8,300 acres (3400 ha), with an estimated future expansion to over 20,000 acres.

No decision has been made regarding development of irrigation on the west side of the river. Estimates of the area that could be served in that region vary from 80,000 to 150,000 acres (although earlier estimates amounted to about 200,000 acres). Water requirements for the two present estimates are about 6.7 and 12.6 m^3/s, respectively in terms of average annual flows. The SSRID project manager sugests a total of 150,000 acres for the combined east and west sides.

Estimates of private irrigation from Lake Diefenbaker are difficult to make. One estimate from a government official is for a foreseeable development of 100,000 acres. This would require approximately 5.0 m^3/s of water annually. Present requirements are for about 1.0 m^3/s.

TABLE 31. SUMMARY OF DIVERSIONS FROM LAKE DIEFENBAKER (m^3/s)

	PRESENT	FUTURES	
		I	II
QU'APPELLE DAM	1.6	2.8[A]	10.2[B]
EAST SIDE P.P.	3.5	5.2[C]	5.2[C]
WEST SIDE P.P.		6.7[C]	12.6[C,D]
PRIVATE IRRIGATION	1.0	3.0[C]	5.0[C]
THERMAL POWER			1.0[C]
	6.1	17.7	34.0

A. QBSB (1972) ESTIMATE OF AVERAGE DIVERSION TO MEET PROJECTED 1985 USES

B. QBSB (1972) ESTIMATE TO MEET PROJECTED 1985 USES IN A VERY DRY YEAR

C. SEE TEXT

D. CALCULATED USING THE HIGHEST ESTIMATE FOR WEST SIDE DEVELOPMENT

A summary of present and possible future diversions from Lake Diefenbaker is contained in Table 31. With maximum irrigation development, and maximum diversion to the Qu'Appelle system, 34 m^3/s could be demanded from the lake, although this is extremely unlikely. The estimates for the Qu'Appelle diversion come from the Qu'Appelle Basin Study Board (1972) and do not include any far-future diversion possibilities to support requirements beyond 1985 in the Qu'Appelle and Assiniboine River basins.

Lake Diefenbaker is also being considered by the Saskatchewan Power Corporation as a possible site for a 1200 MW thermal power site. As of late 1981, no decision had been made as to whether this plant would be located there or at locations near Regina or Gravelbourg. Although no estimates of water requirements have been made public, water consumption at other thermal power plants suggests a make-up water requirement of about one m^3/s.

In addition to diversions, the lake experiences direct losses of water from its 106,000 acre (43 000 ha) surface due to evaporation, estimated at about 10 m^3/s annually. The live storage capacity of four million dam^3 is equivalent to an annual flow rate of about 125 m^3/s. If evaporation, plus a

TABLE 32. RECORDED FLOWS AT SASKATOON AND ST. LOUIS SOUTH SASKATCHEWAN RIVER (EC, 1980A)

SASKATOON	(M^3/S)
MEAN ANNUAL (1912-1979)	268
MEAN ANNUAL (1912-1964)	278
MEAN ANNUAL (1969-1979)	234
LOWEST MONTHLY MEAN (1912-1964) (DEC, 1936)	28
LOWEST MONTHLY MEAN (1969-1979) (SEPT, 1977)	47
LOWEST ANNUAL MEAN (1912-1964) (1931)	129
LOWEST ANNUAL MEAN (1969-1979) (1977)	124
ST. LOUIS (1969-1979)	
MEAN ANNUAL	229
LOWEST MONTHLY MEAN	51
LOWEST ANNUAL MEAN	125

diversion of even 15 m^3/s, amounted to a total loss of 25 m^3/s, then a single very low supply year to the lake (85 m^3/s) would result in a substantial loss of storage if an average of 100 m^3/s were released downstream. If a minimum flow of 50 m^3/s were maintained downstream in a low supply year, lake storage would be maintained, but power production would be reduced.

The production of hydro-electric power at Gardiner Dam (Coteau Creek plant) is described in Chapter VIII.6. To some degree, the regulation of the river for power production is presently limited by other uses. In a dry year, generation output is reduced, and this effect will increase as competing uses expand. In 1980, low-supply conditions resulted in only 90 percent of average supply to Lake Diefenbaker, which decreased power production to 85.7 percent of normal, according to the Saskatchewan Power Corporation.

Downstream of the Gardiner Dam, water is withdrawn by Saskatoon, Outlook and St.Louis; by local industries and several irrigation projects; and also by the Water Supply Board, which supplies raw water to industries west of Saskatoon. The Board also supplies water treated by Saskatoon to other municipalities to the north and southeast. The total withdrawal by the Board presently amounts to about 0.1 m^3/s, while the city withdraws 1.3 m^3/s, and returns 0.8 m^3/s. Despite a modest municipal growth rate and some local industrial expansion, there are no foreseeable constraints to water uses at this location in the basin.

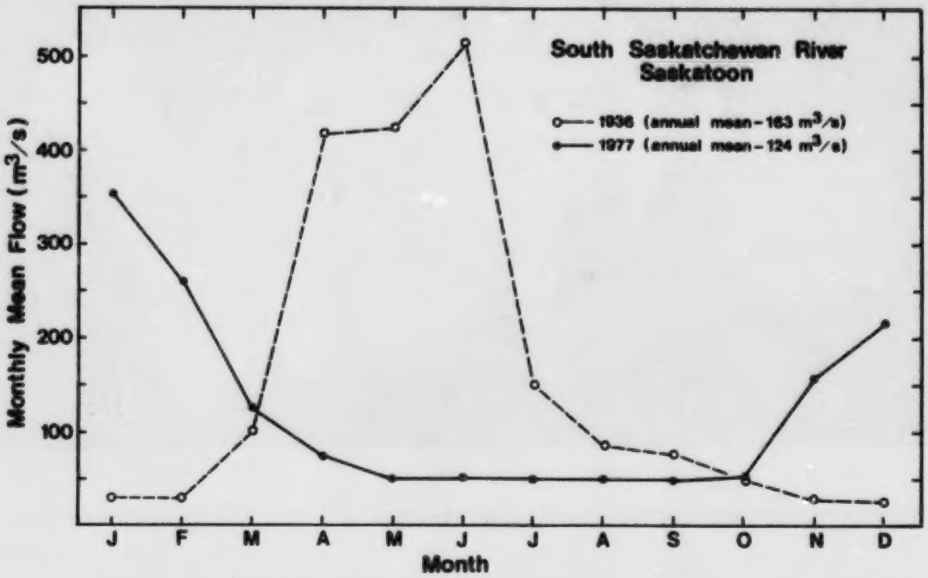
A summary of river flow information at Saskatoon and St. Louis is contained in Table 32. St. Louis is located downstream near the confluence of the river with the North Saskatchewan River.

The figures in the table indicate that the Gardiner Dam has had few adverse effects on critical low-flow values at Saskatoon. The lowest annual flow after construction (1969-79) was very close to the lowest value before the dam (1912-64). However, a comparison of the seasonal variation of flow at Saskatoon for 1936 and 1977 (Figure 48) illustrates the effects of regulation of Lake Diefenbaker in a dry year. Large volumes are released in winter months for power generation, while storage and local diversions reduce summer flows downstream. In 1977 monthly flows were maintained at a minimum of close to 50 m^3/s during summer and autumn for downstream use.

Recorded values at St. Louis show that there is no major difference between river flows at Saskatoon and flows downstream, up to the confluence with the North Saskatchewan River, near Prince Albert.

In summary, large consumptive uses in major upstream tributaries reduce water supplies in the Alberta portion of the South Saskatchewan River basin. Interprovincial apportionment agreements, however, assure a basic supply during dry years in both the Alberta section and downstream as far as Lake Diefenbaker. Agriculture is the principle user in these regions and in the adjacent Cypress Hills, North Slope area. Upstream of Lake Diefenbaker no extensive increase in present use of South Saskatchewan River water or of water in the closed basins is likely.

Figure 48. COMPARISON OF SOUTH SASKATCHEWAN RIVER FLOWS AT SASKATOON BEFORE AND AFTER REGULATION AT THE GARDINER DAM.

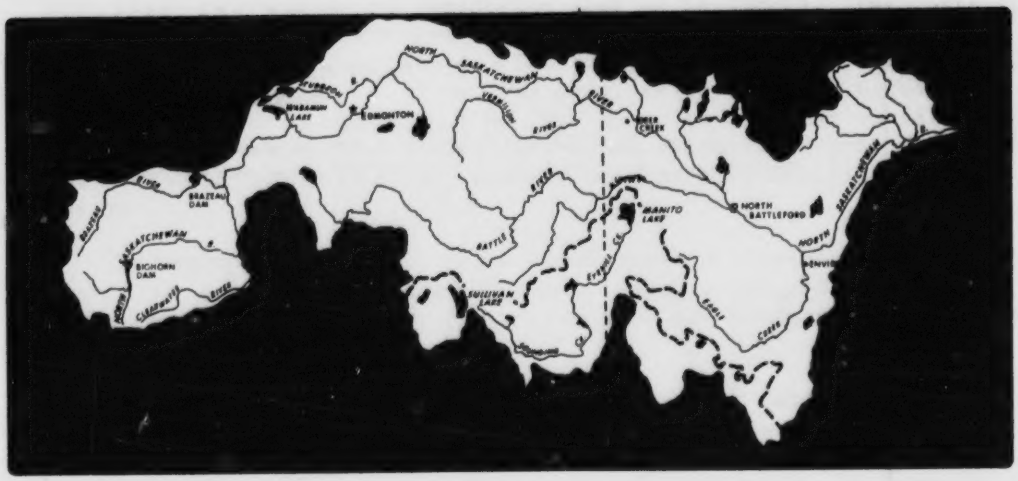


The various users of water from Lake Diefenbaker benefit from its large storage capacity. Nevertheless, there may be limitations on the extent to which it could continue to provide reliable supplies to all users if extensive new demands arise outside the basin. The SNBB (1972) has described several possibilities for diversion to the Souris and Assiniboine Rivers from the Qu'Appelle River Dam on Lake Diefenbaker. Its report also described possible diversions to Lake Diefenbaker from the North Saskatchewan River.

Extensive studies are being undertaken by federal and Saskatchewan agencies concerning water management alternatives for relieving drought conditions in Saskatchewan. These studies could perhaps lead to the assessment of options for increased use of Lake Diefenbaker water in basins to the south.

Present and foreseeable industrial and municipal requirements near Saskatoon are unlikely to experience water shortages if firm flows can continue to be assured from Lake Diefenbaker.

Figure 49. THE NORTH SASKATCHEWAN RIVER BASIN.


NORTH
SASKATCHEWAN
RIVER
STURGEON
R.
WABAMUN LAKE
EDMONTON
VERMILION
RIVER
DEER CREEK
RIVER
BRAZEAU
BRAZEAU DAM
SASKATCHEWAN
R.
NORTH
BIGHORN DAM
CLEARWATER
RIVER
RIVER
BATTLE
MANITO LAKE
NORTH BATTLEFORD
SASKATCHEWAN
NORTH
SULLIVAN LAKE
CR.
EAGLE
CREEK

6. NORTH SASKATCHEWAN RIVER BASIN

The drainage of the North Saskatchewan River (Figure 49) extends from the Rocky Mountains eastward to where it joins with the South Saskatchewan River east of Prince Albert, Saskatchewan. An important tributary is the Battle River, which stretches from the centre of Alberta just south of Edmonton to Battleford, Saskatchewan. Other tributaries in Alberta include several upstream of Edmonton (notably the Clearwater and the Brazeau), the Sturgeon, and the Vermilion. In Saskatchewan, Eagle Creek drains to the North Saskatchewan River from the south and a number of streams flow in from the north. Also included in this section are discussions about an adjacent closed drainage region, the 25 000 km^2 Manito Lake system.

The total area of the North Saskatchewan River basin is over 130 000 km^2, 30 000 km^2 of which is drained by the Battle River. Statistics of flow for the main stem and larger tributaries are found in Table 33.

In the mountains and foothills, the basin is used extensively for recreation. Upstream of the Bighorn Dam the river is unregulated, providing opportunity for fishing, canoeing, and other water-based recreation.

TABLE 33. FLOW STATISTICS (m^3/s) FOR SELECTED POINTS - NORTH SASKATCHEWAN RIVER BASIN
(EC, 1980A; WER, 1980A)

RIVER -	HYDROMETRIC STATION (PERIOD OF RECORD)	MEAN ANNUAL	LOWEST ANNUAL	HIGHEST ANNUAL	LOWEST MONTHLY	HIGHEST MONTHLY	MIN. 5-YR. MEAN	MAX. 5-YR. MEAN
NORTH SASKATCHEWAN -	ROCKY MTN. HOUSE [1] (1913-79*)	141	108 (1929)	204 (1915)	16 (DEC/71)	662 (JUNE/23)		
	EDMONTON [2] (1912-79)	215	140 (1975)	363 (1954)	16 (FEB/37)	1210 (JULY/15)		
	EDMONTON [3] (1912-73)	219	142 (1941)	363 (1954)	16 (FEB/37)	1208 (JULY/15)	176 (1937-41)	270 (1912-16)
	DEER CREEK [2] (1917-79*)	224	151 (1975)	379 (1954)	20 (DEC/49)	1340 (MAY/48)		
	DEER CREEK [3] (1912-73)	232	137 (1949)	379 (1954)	14 (DEC/71)	1342 (MAY/48)	184 (1937-41)	289 (1912-16)
	PRINCE ALBERT [2] (1912-79*)	243	136 (1941)	411 (1954)	19 (FEB/37)	1710 (JULY/15)		
	PRINCE ALBERT [3] (1912-73)	245	136 (1941)	410 (1954)	19 (FEB/37)	1705 (JULY/15)	173 (1937-41)	334 (1912-16)
CLEARWATER -	ROCKY MTN. HOUSE [2] (1914-75*)	26	14 (1919)	50 (1915)	4 (FEB/23)	167 (JULY/15)		
	ROCKY MTN. HOUSE [3] (1912-73)	25	13 (1949)	50 (1915)	4 (FEB/37)	167 (JULY/15)	18 (1918-22)	35 (1912-16)
BATTLE -	UNWIN [2] (1944-79*)	9.3	1.5 (1961)	41.0 (1974)	L 0.1 (MANY)	260 (MAY/74)		
EAGLE CREEK	ENRIVON [2] (1962-79*)	1.6	0.2 (1977)	6.1 (1970)	L 0.1 (MANY)	33.5 (APR/70)		

1. RECORDED FLOWS - NATURAL
2. RECORDED FLOWS - REGULATED
3. COMPUTED FLOWS - NATURAL

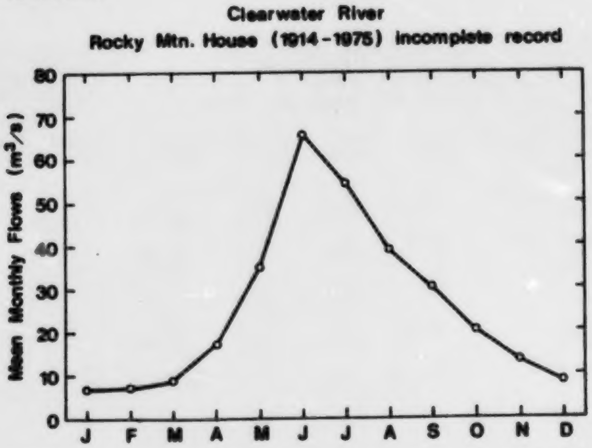
L = LESS THAN

* DISCONTINUOUS RECORD

The development of more formal recreation facilities in this region, specifically resort and conference facilities, has been opposed by organizations such as the Alberta Wilderness Association and the Alberta League for Environmentally Responsible Tourism. The Alberta government has zoned particular areas for recreation as a result of its Eastern Slopes Policy. Of particular interest is the Kootenay Plains area just upstream of Bighorn Dam. A 2785 ha ecological reserve is proposed there, although some organizations would prefer a much larger reserve.

Flow releases from the Bighorn Dam are highest in summer months, about 150 m^3/s. In winter months, releases are about 40-50 m^3/s, but could increase to 65-70 m^3/s. This increase, if implemented, could cause greater flooding in ice-jam situations. Calgary Power is investigating the implications of this.

Figure 50. MEAN MONTHLY FLOWS OF THE CLEARWATER RIVER, CENTRAL ALBERTA.

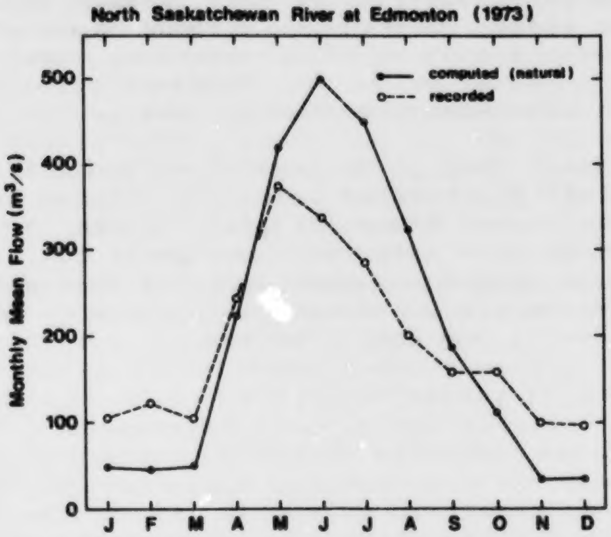


Downstream from the Bighorn Dam, the North Saskatchewan is joined by the unregulated Clearwater River. The natural seasonal variability of flows in this river is demonstrated in Figure 50.

Northward, en route to Edmonton, the river is joined by the Brazeau River, which is regulated by the Brazeau Dam. The total generation capacity of the Bighorn and Brazeau hydro-electric plants is 475 MW. The effects of regulation due to these dams (since 1960) are illustrated by comparison of computed natural and recorded flows at Edmonton for 1973 (Figure 51).

Forestry, mining, and oil and gas operations also are located in the upper parts of the basin. While their demands for water are small, they cause local problems due to effects on water quality. Emissions from sour gas plants, mining effluents and erosion products, drainage problems and erosion from oil and gas operations, and the effects of forestry on drainage and erosion, have all been identified as local concerns.

Figure 51. COMPARISON OF COMPUTED NATURAL FLOWS AND RECORDED FLOWS IN THE NORTH SASKATCHEWAN RIVER AT EDMONTON.



Edmonton requires water for domestic uses and also for some adjacent municipalities, local industry (notably petroleum refineries), and two thermal power plants (Clover Bar and Rossdale). The power plants use once-through cooling. The total present annual withdrawals for municipal use are about 100 million m^3 (3.2 m^3/s). This is expected to increase threefold by 2006.

Edmonton returns virtually the same volume of water as it withdraws from the North Saskatchewan River. This is because storm drainage is included in the primary treatment of the municipal wastes so it is difficult to determine the fraction of water withdrawal that is consumed. Consideration is being given to the addition of tertiary treatment of Edmonton's waste effluent, but concerns about local downstream water quality are not yet major. There is, however, some concern in Saskatchewan regarding the cumulative effects of industrial waste discharges upstream in the Saskatchewan River system. As a centre of its industrial activity, Edmonton is a possible source of materials causing concern.

Two thermal power generation plants (Wabamun and Sundance) are located just west of Edmonton at Wabamun Lake. The Wabamun plant uses lake water for cooling. Although supply is not an issue, the effects of the heated effluent on the quality of the lake has caused concern regarding recreation, commercial fishing, and local native uses. The Sundance plant uses North Saskatchewan River water instead of the lake water.

Additional power plants approved are Keephills (1983-4) and Genesee (1987-8), both of which will withdraw water from the North Saskatchewan River (Chapter VIII.6). Sites have been identified for three additional power plants that could withdraw water from the North Saskatchewan River. Present and foreseeable water requirements for thermal power generation are summarized with other uses in this area in Table 34.

Industrial expansion expected to occur at or near Edmonton includes refinery and related developments whose water requirements may reach between three and six m^3/s. Nevertheless, at this point in the basin, water supply is not expected to result in offstream use constraints in the foreseeable future. Consumptive usage is small compared to supply. For this reason no tabular summary of basin-wide uses is presented. Specific information about uses is found in Chapter VIII.

TABLE 34. WATER WITHDRAWALS FROM NORTH SASKATCHEWAN RIVER NEAR EDMONTON (m^3/s)

	PRESENT	FORESEEABLE -	YEAR
MUNICIPAL	3.2 (0)	9-10 (0)	2006
INDUSTRIAL	0.9 (0.5)	3-6 (2-4)	2000
THERMAL POWER	2.0 (1.0)	8-9 (4-5)	2000
TOTAL	6.1 (1.5)	20-25 (6-9)	

( ) - CONSUMED

The Sturgeon River drainage provides some local agricultural supply, but is considered to be primarily a source of recreation and wildlife habitat. The major problem identified in this system is flooding of urban and agricultural lands.

At some location upstream of the Vermilion River, water could be diverted from the North Saskatchewan to the Cold Lake heavy oil developments (Chapter VIII.4). The initial diversion would be about one m^3/s. The full extent of oil development in that region is difficult to predict, though the simultaneous operation of three to six plants is not an unrealistic possibility. A six-plant scenario could require about six m^3/s. However, Ryckborst (1981), assuming six large-scale plants with water recycling, has estimated a possible demand of 13 m^3/s. In either case, water would have to be imported from either the North Saskatchewan River or possibly the Athabasca River.

In the Vermilion River system, flooding and water quality degradation by municipal and agricultural wastes have been identified as problems. Low winter flows prevent any industrial development. Recommendations have been made for flood control and waste treatment measures in this basin.

Alberta is committed to provide 50 percent of the natural flow of the North Saskatchewan River across the Saskatchewan boundary, upstream of the Deer Creek water survey station. The mean annual and lowest annual mean natural flows computed at that point (1912 -1973) are about 230 m^3/s and 135 m^3/s, respectively (Table 33). The lowest recorded value at Deer Creek is about 150 m^3/s.

There is no evidence that Alberta's apportionment obligations would affect the availability of water for foreseeable developments in the Alberta portion of the basin, unless massive diversions of water were made from the North Saskatchewan River to other basins. In addition to possible Cold Lake diversions, the SNBB identified three major diversion possibilities. As mentioned earlier, the Alberta government appears to be opposed to major interbasin transfers.

The Prairie Provinces Water Board monitors water quality at the Deer Creek location and publishes a summary of data and statistics of "exceedences" of specific objectives for each parameter. At Deer Creek, between 1974 and 1981, 80 percent of measurements of total phosphate and 75 percent of total nitrogen values exceeded objectives. A move to tertiary treatment at Edmonton would likely contribute to a reduction of these nutrient values.

The Battle River drains a significant portion of the total North Saskatchewan River basin, but because it lacks the high yield of the mountain and foothills regions, its flow is proportionally much smaller and more variable. Because of potentially high demands for water in this basin, due to extensive coal and petroleum reserves, an evaluation of supply and demand has been conducted by Alberta Environment.

A summary of Alberta Environment's present and predicted demands for the Battle River, together with statistics of supply, are contained in Table 35. Near and intermediate future measures recommended include internal flow increases, restrictions on highly consumptive uses, and additional regulatory works. However, far future needs will likely exceed available supply, considering the commitment to provide 50 percent of the natural flow to Saskatchewan. Importation of water from either the North Saskatchewan or the Red Deer Rivers would be necessary to meet far-future use requirements. If approved, a diversion is feasible by the mid-1990s (Alberta Environment, 1981b).

The PPWB water quality summary for the boundary location at Unwin indicates high exceedence percentages for manganese (79), total nitrogen (96), dissolved oxygen (30), phenols (30), and total phosphate (49). Specific conductance, the measure of total dissolved solids, reaches values over three times as high as in the North Saskatchewan River. This is typical of the small, low-flow streams originating in the Interior Plains.

In the Saskatchewan portion of the Battle River basin, consumptive uses are less extensively developed. Supply from Alberta can be as low as half the annual natural yield in that province. At Unwin (Table 35), the lowest computed natural flow (1912-1973) is about 1.2 m^3/s, which would provide a minimum 0.6 m^3/s to Saskatchewan. It is apparent that the water in this basin is not sufficient to support any large future developments such as large-scale heavy oil extraction or irrigation.

The Manito Lake closed drainage area includes the Sounding Creek in Alberta, Eyehill Creek in Alberta and Saskatchewan, and a few evaporation lakes in both provinces. Agriculture is the predominant industry in the region, but irrigation is limited to under 3,000 acres (1200 ha) because of unreliable water supplies. Sounding Creek, for example, frequently experiences flows at or near zero, even in the spring months. The Special Areas include a part of this closed drainage area, and a study by Alberta Environment of water supply, management, and use in the Sounding Creek basin is now nearing completion.

TABLE 35. SUPPLY/DEMAND ANALYSIS - BATTLE RIVER BASIN

COMPUTED NATURAL SUPPLY AT UNWIN, SASKATCHEWAN (1912-73) - M^3/s

MEAN ANNUAL FLOW	7.5
LOWEST ANNUAL FLOW	1.2
LOWEST MONTHLY FLOW	0
LOWEST 5-YR ANNUAL MEAN	2.8

CONSUMPTION IN A DRY YEAR* M^3/s

(BASED ON EQUIVALENT ANNUAL FLOW)	1976	1986	2001**	2001***
MUNICIPAL	0.01	0.02	0.04	0.04
IRRIGATION	0.30	0.38	0.48	0.48
OTHER AGRICULTURE				
INDUSTRIAL	0.07	0.09	0.44	1.78
THERMAL POWER	0.10	0.15	0.29	0.44
TOTAL	0.48	0.64	1.25	2.74

* - ALL FIGURES FROM ALBERTA ENVIRONMENT (1981B)

** - MINIMUM DEVELOPMENT

*** - MAXIMUM DEVELOPMENT

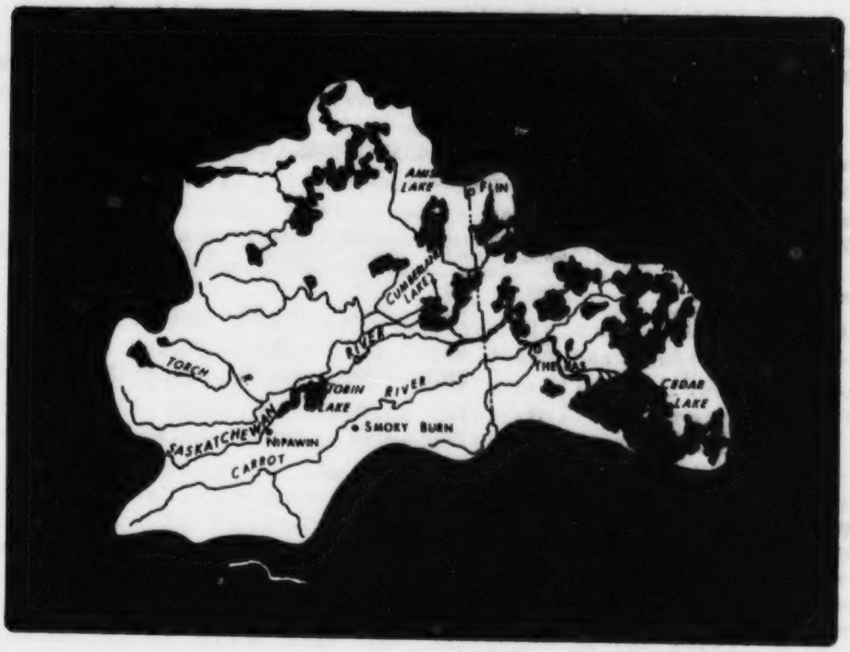
Eagle Creek, which joins the North Saskatchewan River near Saskatoon, effectively drains only 18 percent of its 12 000 km^2 basin. Like other streams rising in the Interior Plains, its flow is small and variable, with extensive periods of zero flow (Table 33).

From Eagle Creek, the North Saskatchewan winds northeastward to its confluence with the South Saskatchewan, just past Prince Albert. In this part of the basin, consumptive use of water for municipal and industrial purposes (including a major pulp mill) are very small relative to the river flow.

In summary, water uses in the North Saskatchewan River basin that rely on the main stem river for supply are not constrained at present, nor are constraints identified for the foreseeable future. Use limitations exist and will become more severe in some tributary basins, especially Battle River and Eagle Creek.

Water quality in low-flow tributaries can be poor, affecting fish and recreation. Elsewhere, water quality problems of a serious nature have not yet been identified in flowing waters.

FIGURE 52. THE SASKATCHEWAN RIVER BASIN.


AMIS
LAKE
FLIN
CUMBERLAND
LAKE
RIVER
TORCH
TOBIN
LAKE
RIVER
SASKATCHEWAN
NIPAWIN
SMOKY BURN
CARROT
THE PAS
CEDAR
LAKE

7. SASKATCHEWAN RIVER BASIN

The North and South Saskatchewan Rivers join just east of Prince Albert to form the Saskatchewan River (Figure 52). At that point these tributaries drain an area of more than 280 000 km^2.

Information in the foregoing sections dealing with each of these rivers describes their contributions to the Saskatchewan River. The mean annual drainage from the North and South Saskatchewan Rivers is 245 and 230 m^3/s, respectively. In eastern Saskatchewan, the river widens and enters a lake complex which continues into Manitoba, eventually leading to Lake Winnipeg through Cedar Lake. A major unregulated tributary, the Carrot River, joins just upstream from The Pas, Manitoba. Its supply to the Saskatchewan River is, on average, about 25 m^3/s.

At Grand Rapids, Manitoba, the river drains 363 000 km^2, with a mean annual flow of about 700 m^3/s. Statistics of flow for key locations in the basin are contained in Table 36.

TABLE 36. FLOW STATISTICS (m^3/s) FOR SELECTED POINTS - SASKATCHEWAN RIVER BASIN
(EC, 1980A; WER, 1980A)

RIVER	-	HYDROMETRIC STATION (PERIOD OF RECORD)	MEAN ANNUAL	LOWEST ANNUAL	HIGHEST ANNUAL	LOWEST MONTHLY	HIGHEST MONTHLY	MIN. 5-YR MEAN	MAX. 5-YR. MEAN
SASKATCHEWAN	-	THE PAS[2] (1913-79*)	669	307 (1941)	1170 (1916)	54 (FEB/30)	2850 (JUNE/48)		
		THE PAS[3] (1912-73)	700	341 (1941)	1175 (1916)	38.6 (DEC/72)	2923 (JUNE/48)	457 (1937-41)	943 (1913-17)
CARROT	-	SMOKY BURN[1] (1955-79**)	19	2.7 (1961)	45 (1979)	0.07 (OCT/61)	205 (MAY/56)		

1. RECORDED FLOWS - NATURAL
2. RECORDED FLOWS - REGULATED
3. COMPUTED FLOWS - NATURAL

* DISCONTINUOUS RECORD

** FOR THE PERIOD MARCH TO OCTOBER, INCLUSIVE

Water requirements for this basin are described in Chapter VIII. Hydro power and mining are the most significant developments requiring or affecting the water resource. Renewable resource utilization and recreation are also important uses, and they can be in conflict with other development if resulting river regulation causes flooding, erosion, or sedimentation problems.

In Saskatchewan, a hydro-electric dam is situated at Squaw Rapids (Tobin Lake) and a new power dam is under construction near Nipawin. Other possible sites for future development by the Saskatchewan Power Corporation are at Choiceland and The Forks both upstream from Tobin Lake. In each case, concern exists about possible local environmental effects, particularly due to flooding by the new impoundments. Studies on possible effects at the Choiceland and The Forks locations are expected to be completed in 1981. The timing of these projects (which could total 600 MW) could be delayed if the Western Power Grid is approved (Chapter VIII.6).

None of the three potential hydro sites would significantly affect streamflow patterns, since they do not involve large reservoir development. However, dams such as at Squaw Rapids act as traps of materials that originate upstream in the North and South Saskatchewan Rivers. A recent study by Environment Canada (Birkholtz, et al, 1980) has found that contamination of organisms in Tobin Lake appears to be due to waste discharges upstream, possibly as far west as Edmonton. Similar situations could develop at the proposed new dams.

Downstream, the Saskatchewan delta extends from above Cumberland Lake to Cedar Lake. The delta has been, and continues to be, the centre of water use conflict between waterfowl, agriculture, and subsistence interests. The regulation of the river by present and future hydro sites upstream has altered the natural flooding of the delta. Ducks Unlimited (DU) has developed habitat restoration and protection projects in both provinces. In Saskatchewan, this is centred around Cumberland Lake.

In Manitoba, DU has been granted a license to develop the Saskram Marsh area near the confluence of the Saskatchewan and Carrot Rivers. With the success of a nearby community pasture project by Manitoba and PFRA, farmers have resisted the Saskram project, urging the use of that land for additional hay and pasture production. Farmers have indicated that the DU development has resulted in the loss of 1 million bales of hay annually. Manitoba is presently planning a review of conflicting interests in this area.

Just east of The Pas, DU is also developing the Summerberry Marsh, which is protected from the hydro impoundment (Cedar Lake) by dykes.

In each marsh development case, local native groups are interested in ensuring that habitat is protected for trapping and fishing uses. The natives are also interested in the agricultural aspects, so they would seem to benefit from solutions which optimize competing interests.

At the mouth of the Saskatchewan River, a hydro station is located at Grand Rapids. Local storage in Cedar Lake is significant (over 8 million dam^3) and provides a reliable supply for this hydro facility.

Although there is considerable agriculture in the Saskatchewan River basin, especially in the Carrot River and Torch River basins, the demand for irrigation water is small. Water quality problems exist for some stockwatering usage, though this problem is not as widespread as in southern basins.

In this basin an added concern is related to atmospheric emissions from mining smelters, which have caused contamination of nearby lakes. Smelter emissions at Flin Flon have been the subject of extensive study, due to concern about the effects of metals and sulphur emissions on local vegetation, water, fish, and wildlife. In part due to concern about pollution of local waters, and in part due to increasing concern in Saskatchewan about violations of air quality standards and the threat of "acid rain", licensing of emissions from Flin Flon is under review.

In summary, water supply to offstream users is not an issue in the Saskatchewan River basin. Consumptive uses in both Alberta and Saskatchewan affect flows in the Saskatchewan River. One important effect of increased upstream usage would be loss of hydro power potential. The environmental effects of all uses upstream and regulation within this basin are also considered to be important to uses in the Saskatchewan delta.

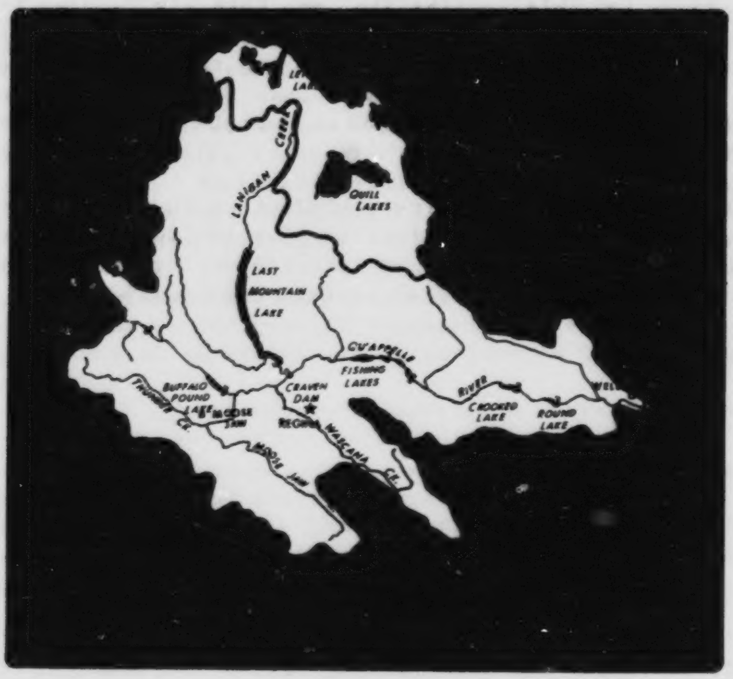
At present, no significant constraints exist due to water quality degradation, except locally near the large mine smelter. However, any substantial decrease in the quality in either of the major upstream tributaries could seriously affect river fish populations in the future.

Under the PPWB Master Agreement on Apportionment (PPWB, 1969), Saskatchewan is permitted to consume much more water than it presently uses. Saskatchewan is required to provide Manitoba with one-half the flow it receives from Alberta, plus one-half of the natural flow arising in Saskatchewan, in this river basin. In fact, the recorded mean annual flow at The Pas (1913-1979) is about 670 m^3/s, which is very close to the computed total natural flow (1912-1973) of 700 m^3/s. Much of its excess water occurs in the North Saskatchewan, which is presently not substantially used either in Alberta or Saskatchewan. At present, even in very dry years, there is also excess water from the South Saskatchewan part of the system. Saskatchewan has an interest in protecting these flows as supply to its expanding hydro operations along the Saskatchewan River, although more valuable upstream uses would likely be given higher priority.

One possible future upstream use would be an increased diversion of South Saskatchewan River waters to southern basins. In addition to this possibility, the SNBB (1972) also described the feasibility of a diversion to the Saskatchewan River from the Churchill River via streams passing through Amisk Lake (425 m^3/s). A diversion from Cedar Lake to the Assiniboine River (20 m^3/s) via Lake Winnipegosis and Lake Manitoba was also described.

Issues in Manitoba are related to the management of the delta waters to the satisfaction of wildlife, agriculture, and subsistence users. There is no significant threat to hydro power use, because of the large local storage capability.

Figure 53. THE QU'APPELLE RIVER BASIN.


LANIGAN CREEK
QUILL LAKES
LAST MOUNTAIN LAKE
QU'APPELLE
FISHING LAKES
RIVER
CRAVEN DAM
BUFFALO POUND LAKE
MOOSE JAW
REGINA
THUNDER CR.
MOOSE JAW
WASCANA CR.
CROOKED LAKE
ROUND LAKE

8. QU'APPELLE RIVER BASIN

The Qu'Appelle River basin extends from the South Saskatchewan River basin in southwestern Saskatchewan to just inside Manitoba where it flows into the Assiniboine River (Figure 53). The river, which drains a surface area of about 50 000 km^2, is highly regulated. In 1968, a gravity diversion from Lake Diefenbaker was established, with a channel capacity to the Qu'Appelle River of just over 11 m^3/s.

The drainage system is made up of the mainstream Qu'Appelle River and a number of tributary creeks, rivers, and lakes. Buffalo Pound Lake is a small reservoir from which Regina and Moose Jaw draw their municipal supplies. The narrow 75 km long Last Mountain Lake extends northward from the river. The Fishing Lakes (Pasqua, Echo, Mission, and Katepwa), Crooked Lake and

Round Lake are located in the main river channel in its central and lower reaches. The channel capacity of the river varies considerably throughout its length, between three m^3/s and just over 42 m ^{3}/s.

The 11 340 km^2 Quill Lakes closed drainage area is included in this section. The Saskatchewan Research Council (Whiting, 1977) and others have conducted numerous studies on the water resources of this area.

TABLE 37. FLOW STATISTICS (m^3/s) FOR SELECTED POINTS - QU'APPELLE RIVER
(EC, 1980A; WER, 1980A)

RIVER	-	HYDROMETRIC STATION (PERIOD OF RECORD)	MEAN ANNUAL	LOWEST ANNUAL	HIGHEST ANNUAL	LOWEST MONTHLY	HIGHEST MONTHLY	MIN. 5-YR MEAN	MAX. 5-YR MEAN
QU'APPELLE	-	ABOVE BUFFALO POUND LAKE^2 (1968-79)	2.05	1.24 (1975)	2.98 (1974)	0 (JUNE/69)	22.8 (APR/74)		
		BELOW CRAVEN DAM ^{2} (1955-79)	5.23	0.3 (1962)	20.7 (1974)	0.02 (OCT/62)	49.1 (MAY/74)		
		TANTALLON ^{2} (1951-74)	7.75	0.19 (1961)	37.5 (1955)	0 (MANY)	135 (MAY/55)		
		WELBY ^{2} (1942-79*)	11.5	2.54 (1978)	26.5 (1976)	0.36 (FEB/78)	141 (MAY/55)		
		WELBY ^{3} (1912-73)	6.2	0.2	39.7	.03 (MANY)	141 (MAY/55)	0.8 (1937-41)	21.4 (1953-57)

1. RECORDED FLOWS - NATURAL
2. RECORDED FLOWS - REGULATED
3. COMPUTED FLOWS - NATURAL

* DISCONTINUOUS RECORD

Records of flow above Buffalo Pound Lake, prior to the diversion from the South Saskatchewan River, are typical of a small Interior Plains river. There was a high spring runoff, and almost zero-flow conditions could occur as early as mid-summer. With the diversion, annual flows have averaged about 2 m^3/s, with considerable annual and seasonal variation, yet with reliable late summer and autumn supplies. Statistics of supply for several locations throughout the basin are contained in Table 37.

The Qu'Appelle basin is an example of a case where careful manipulation of supply is necessary to try to accommodate a great variety of users. In low-supply years, especially in the upper part of the basin, available water must be skillfully controlled. Water withdrawals in this basin are described in Chapter VIII, and summarized in Table 38. The basin presently contains no dominating consumptive use. The uses are varied and highly competitive, as water supply is not large.

TABLE 38. SURFACE WATER WITHDRAWALS (m^3/s) - QU'APPELLE RIVER BASIN

	PRESENT	FORESEEABLE
MUNICIPAL - REGINA	0.6	0.7 (1996)
- OTHER	0.7	0.8
INDUSTRIAL	0.2	0.7
IRRIGATION	0.3	1.9
OTHER AGRICULTURE	0.3	0.3
THERMAL POWER		1.0
TOTAL	2.1	5.4

Past releases to the Qu'Appelle River from the Qu'Appelle River Dam on Lake Diefenbaker have been primarily for purposes of maintaining Buffalo Pound Lake levels. That is the source of supply for the cities of Regina and Moose Jaw and for the Kalium potash plant. It is also used extensively for water-based recreation. However, in 1981 water was released to the Qu'Appelle at maximum channel capacity not only to meet the needs at Buffalo Pound Lake but, to the extent possible, needs in other parts of the basin.

Regina presently requires an average of about 1.0 m^3/s, about 40 percent of which is supplied from ground water. Foreseeable requirements are about 1.2 m^3/s by 1996 (see Chapter VIII.5). Future problems of supply, related to conveyance and storage facilities, are possible without new works and strict management policies.

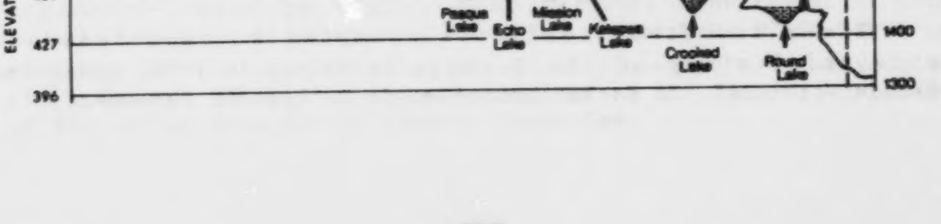
During 1975 Regina installed a new tertiary treatment plant for its sewage discharge, which goes to Wascana Creek. Return flow volumes are about 82 percent of withdrawals, although this includes flows from some combined storm and sanitary sewers. The city of Moose Jaw has decided to develop an effluent irrigation system which will begin using waste water to irrigate 1000 acres.

The major industrial demand from Buffalo Pound Lake is about 0.1 m^3/s for the Kalium potash plant near Moose Jaw. This water is totally consumed. The possibility exists of the location of a Saskatchewan Potash Corporation fertilizer plant requiring up to 0.5 m^3/s from Buffalo Pound Lake, which also would be totally consumed. Potash plants in the lower part of the basin presently use ground water for most of their requirements. SPC is presently considering a site near Regina for a 1200 MW thermal power plant. A plant of this size could require an annual supply of 1.0 m^3/s.

From the above, considering the present diverted supply from Lake Diefenbaker, future water needs in the upper basin will be increasingly competitive, unless increased supplies and improved conveyances are developed.

Control structures in the Qu'Appelle River downstream of Buffalo Pound Lake are operated for flood control, irrigation, fisheries benefits, and maintenance of lake levels for recreational purposes. A profile of the river and its controls is illustrated in Figure 54.

Figure 54. SCHEMATIC DIAGRAM OF THE QU'APPELLE RIVER AND ITS CONTROL STRUCTURES.


Qu'Appelle River Dam
Saskatchewan-Manitoba Border
579
549
518
488
457
427
396
ELEVATION IN METRES
1900
1800
1700
1600
1500
1400
1300
ELEVATION IN FEET
Lake Diefenbaker
Buffalo Pound Control Structure
Buffalo Pound Lake
Craven Control Structure
Echo Lake Control Structure
Katepwa Weir
Crooked Lake Control Structure
Round Lake Control Structure
Pasqua Lake
Echo Lake
Mission Lake
Katepwa Lake
Crooked Lake
Round Lake

Northeast of the city of Moose Jaw, the Qu'Appelle River is joined by the Moose Jaw River. The flow just below the confluence, though complicated by regulation upstream, has averaged about 5.2 m^3/s since 1968. Between the Buffalo Pound control and the Last Mountain Lake control, Wascana Creek also joins the mainstream, providing a mean annual flow of about 3 m^3/s, most of it during April.

Downstream, controls exist at the Craven Dam on the Qu'Appelle River, and a dam at the south end of Last Mountain Lake. In high-flow periods, both dams are left open, allowing flood water to pass downstream and also into the lake. The lake therefore acts as a natural storage of flood waters which can then be released under control during drier periods.

Further regulation occurs downstream at two locations on the Fishing Lakes. Nevertheless, spring flows continue to exhibit great variation. The levels of the Fishing Lakes are difficult to control, particularly because the Katepwa Weir and the gated control structure are not designed for level control during large floods. Efforts are made to operate upstream controls so as to minimize flooding problems and reduce shore erosion in the spring, maintain appropriate levels for recreation in the summer, and serve other users as well as possible. Control dams on Crooked Lake and Round Lake are able to maintain desired water levels in these lakes except during periods of very high or very low supply. For example, in the early months of 1981, the levels of these lakes became too low because of insufficient inflow.

These six lakes, located in the middle and lower portions of the basin, are important for recreation, and commercial and subsistance uses by native groups. Flow releases upstream and from the controls on the lakes are managed in part to reduce flooding and erosion of beach and cottage zones, maintain levels for recreation, provide for needs of fish populations, improve water quality, and maintain wildlife habitat.

The success of these efforts varies. Some cottagers desire lower lake levels in order to prevent shoreline erosion and provide more beaches. Others prefer high levels to allow better fishing, boating, and swimming, and to reduce the effects of algae and weed growth in the lakes (Qu'Appelle Valley Management Board).

These and other conflicts prompted a joint federal-provincial study of the Qu'Appelle Valley in 1972, under the Canada Water Act. A Saskatchewan-Canada Qu'Appelle Agreement, signed in 1975, provided $33.7 million for environmental improvement and development of tourism and recreation. Implementation of projects were subsequently organized through a Qu'Appelle Valley Implementation Office.

The flooding problem has been addressed in part through a program of dyke construction and channel improvement. Works protect not only urban centres but also agricultural and recreation lands. A Flood-Prone Land Purchase Program has been put into effect.

The channel improvement program is aimed at achieving a minimum of 14 m^3/s channel capacity in the river between Last Mountain Lake and the outlet of Round Lake (Figure 52). However, this and other aspects of the implementation program have aroused the concern of the several Indian bands located in the valley. The Qu'Appelle Valley Indian Development Authority has listed several issues which it feels need to be addressed through more direct participation by natives in the planning and implementation program. These issues include "losses of and damages to improvements on the Reserves as a result of water level control decisions". For a more through presentation of the views of the native groups see "The Qu'Appelle River Conveyance System: Impacts on Indians in the Valley" (Rieber-Kremers & Associates Ltd. and UNIES, 1980). By late 1981, the QVIDA had conditionally agreed to conveyance improvements.

The recreational use of the Qu'Appelle Valley is an important consideration in the implementation program. Additional lands are being purchased for recreational development and fisheries and wildlife protection. Recreation facilitites will continue to grow, and the area is expected to develop as an even more important centre for recreation in the province. The potential for conflict of this development with the traditional uses of the valley waters by natives could increase.

Summaries of irrigation use and other agricultural uses throughout the basin are included in Chapter VIII. The present use of about 10 000 dam^3 of water per year (0.3 m^3/s) for irrigation could increase up to six to eight times that with development of potential acreage. However, an expansion of that magnitude would be difficult to supply, particularly in the upper part of the basin where municipal and possible industrial expansion would be highly competitive. The relief of this situation by additional diversion from Lake Diefenbaker is limited by the capacities of the diversion canal and sections of the river. These are small compared to the 74 m^3/s capacity of the outlet from the Qu'Appelle River Dam.

Other agricultural uses are now moderately constrained for reasons of supply and quality. Extensive expansion in upland areas would face serious limitations, but is not expected to occur.

Water quality is generally poor throughout the basin. Mercury levels in fish have been of concern, and upstream sources have been identified (e.g., Gummer, 1980). Sulphate and chloride concentrations are very high, while phenols exceed drinking water standards (FEC, 1977). Phosphate levels are also very high, and have contributed extensively to the degradataion of the lakes. Phosphorous reductions from municipal and agricultural sources are also part of the implementation program mentioned above. Prior to installation of tertiary treatment, Regina contributed 56 percent of the phosphorous loading.

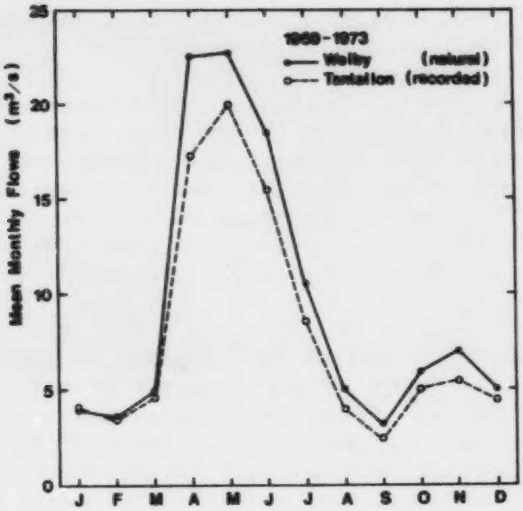
Another serious quality issue in this basin concerns pesticide residues from agricultural practices. The Qu'Appelle River has been found to carry significant concentrations of several different pesticides, in some cases the highest levels of any Canadian waters (Gummer, 1979). Continued or expanded usage of these in local agriculture could increase concern for the health of fish, wildlife, and humans.

The PPWB has identified iron, manganese, total nitrogen, and total phosphate as parameters whose values exceed recommended objectives a high percentage of the time in this river at the Manitoba border. Specific conductance, a measurement of total dissolved solids, is also quite high at this point. This is quite typical of rivers arising on the Interior Plains.

Just upstream of the confluence of the Qu'Appelle River with the Assiniboine River, flow has been recorded at Tantallon (up to 1974) and Welby (1942-55 and 1974-79) (Table 37). Natural flow has also been computed for the Welby location. The 5-year moving mean values of computed natural flow for this location indicate that the driest period since 1912 was from 1937 to 1941. The wettest period was between 1953 and 1957.

Recorded flows just upstream at Tantallon, for a five year period following the commencement of the diversion from Lake Diefenbaker (1969-73), are compared with the computed natural flows for that period at Welby in Figure 55. Despite regulation, the Tantallon data indicate high annual and seasonal variabilities, similar to the Welby data.

Figure 55. COMPARISON OF RECORDED FLOWS AND COMPUTED NATURAL FLOWS IN THE LOWER QU'APPELLE RIVER.



Because of the complexity of the Qu'Appelle River system, computations of natural flow are difficult, and values must be used with caution. However, a four-year average (1977-1980, inclusive) of annual mean natural flow values at Welby ($4.4 m^3/s$) added to the average diversion from Lake Diefenbaker for that period ($2.0 m^3/s$) suggests an average total surface supply rate of $6.4 m^3/s$. The average recorded flow at Welby for the same period was about $5.3 m^3/s$, indicating a net consumptive use in the basin of about 17 percent of total supply, or 25 percent of natural supply.

Under the Master Agreement on Apportionment (PPWB, 1969), Saskatchewan is required to pass a minimum of 50 percent of the natural flow of the Qu'Appelle River to Manitoba. One-half of the lowest computed natural flow at Welby amounts to $0.1 m^3/s$, while one-half of the mean annual value is about $3 m^3/s$. This requirement is an essential consideration in the planning of measures to satisfy projected consumptive uses in the basin.

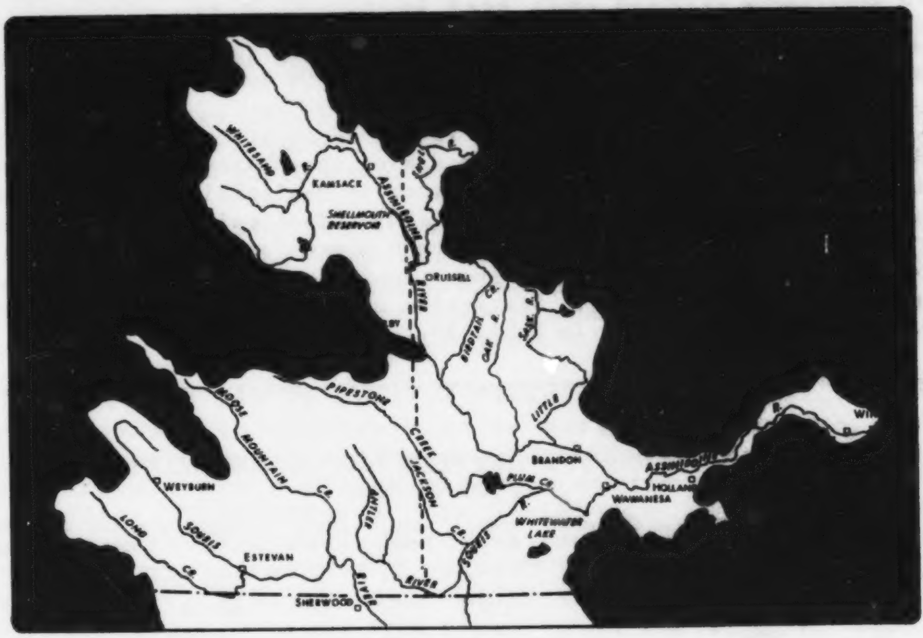
In summary, this basin has become the focus of considerable water management attention. It contains one-third of the population of Saskatchewan, and has been recognized as a region with serious water-related problems. In its upper reaches it will continue to face development limitations due to water shortages, unless larger diversions can be made from Lake Diefenbaker. In the central and lower portions, although improvements to water quality and decreased flooding are expected, some aspects of water quality could become more serious. Water use conflicts will continue to challenge water managers.

In low-flow years the basin should continue to be able to meet apportionment obligations to Manitoba, because of diversions from Lake Diefenbaker. Although the PPWB has established water quality "objectives", no actual quality requirements have yet been set for the border crossing on this river. If these are eventually developed, satisfactory maintenance of required levels of TDS, nutrients, and pesticides will be an additional challenge for water managers.

In addition to diversions for purposes within the Qu'Appelle basin, the feasibility of using parts or all of the river as conveyances of water from Lake Diefenbaker to the Souris and Assiniboine Rivers has been studied (SNBB, 1972; SRBSB, 1978). Although no proposals have been put forward by governments, some portions of these diversion possibilities could conceivably be considered as alternatives for addressing future drought problems in southern Saskatchewan and Manitoba.

Water uses in the Quill Lakes closed drainage area are small. Because of intermittent supplies and poor water quality, opportunities for expanded usage are limited.

Figure 56. THE ASSINIBOINE RIVER BASIN.


WHITESAND R.
KAMSACK
SHELLMOUTH RESERVOIR
ASSINIBOINE
SHELL
R.
RUSSELL
RIVER
BY
BIRDTAIL CR.
OAK R.
SASK. R.
LITTLE
PIPESTONE
CREEK
MOOSE MOUNTAIN CR.
WEYBURN
LONG CR.
SOURIS
ESTEVAN
ANTLER
JACKSON
CR.
RIVER
SOURIS
RIVER
SHERWOOD
BRANDON
PLUM CR.
R.
WHITEWATER LAKE
WAWANESA
HOLLAN
ASSINIBOINE
R.
WI

9. ASSINIBOINE RIVER BASIN

The major components of the Assiniboine River basin are the Assiniboine River and the Souris River (Figure 56). Because of its size and its special nature as an international river, some important aspects of the Souris are treated separately.

The headwaters of the Assiniboine River are located in eastern Saskatchewan and include drainage from the Whitesand River. The Assiniboine basin then extends southeastward in a relatively narrow band to where the Assiniboine River meets the Qu'Appelle River in Manitoba. En route, it is joined by the Shell River from the east. Farther south, the Birdtail, Oak, and Little Saskatchewan Rivers flow in from the north.

Southeast of Brandon, the Souris River outflow reaches the Assiniboine. The Souris is an international river that crosses to North Dakota from Saskatchewan, then returns to Manitoba. It drains a total surface area of over 60 000 km^2, 40 000 km^2 of which is in Canada. Its major tributaries in Canada include Long

Creek, Moose Mountain Creek, Antler River, Jackson Creek, and Plum Creek.

Downstream from the Souris, the Assiniboine proceeds to its union with the Red River at Winnipeg. The total drainage area supplying water at this point is over 150 000 km^2.

The Assiniboine River is regulated in its upper reaches in Saskatchewan, primarily by a dam on the Whitesand River. The impact of this on flows at Kamsack is negligible, and computed natural flows there are virtually identical to the observed record. The Kamsack records indicate a mean annual flow of about 5.7 m^3/s, with a high spring runoff, and occasional very low autumn and winter flows. Statistics of flow at points throughout the basin are contained in Table 39.

TABLE 39. FLOW STATISTICS (M^3/S) FOR SELECTED POINTS - ASSINIBOINE RIVER BASIN
(EC, 1980A; WER, 1980A)

RIVER	- HYDROMETRIC STATION (PERIOD OF RECORD)	MEAN ANNUAL	LOWEST ANNUAL	HIGHEST ANNUAL	LOWEST MONTHLY	HIGHEST MONTHLY	MIN. 5-YR MEAN	MAX. 5-YR MEAN
ASSINIBOINE	- KAMSACK [2] (1944-79*)	5.7	0.18 (1961)	14.3 (1976)	0 (MANY)	132 (MAY/55)		
	KAMSACK [3] (1912-73)	7.7	0.14 (1940)	54.0 (1922)	0 (MANY)	286.3 (MAY/22)	0.56 (1937-41)	24.4 (1921-25)
	BRANDON [2] (1913-79)	32.8	3.7 (1940)	99.0 (1955)	0.65 (FEB/40)	432.0 (MAY/22)		
	HEADINGLEY [2] (1914-79)	48.6	7.3 (1940)	137.0 (1955)	1.8 (JAN/40)	478.0 (MAY/23)		
	HEADINGLEY [3] (1912-73)	47.7	7.3 (1940)	137.0 (1955)	0.48 (JAN/63)	477.5 (MAY/23)	13.4 (1937-41)	96.8 (1953-57)
SOURIS	- SHERWOOD [2] (1931-79)	4.1	0.05 (1931)	24.5 (1976)	0 (MANY)	191 (APR/76)		
	SHERWOOD [3] (1912-74)	3.4	0.08 (1931)	11.0 (1969)	0 (MANY)	109 (APR/69)	0.7 (1931-35)	5.7 (1970-74)
	WAWANESA [2] (1912-79*)	13.2	0.13 (1937)	81.6 (1976)	0 (MANY)	488 (APR/76)		
	WAWANESA [3] (1912-74)	10.8	0.28 (1931)	42.9 (1969)	0 (MANY)	226 (APR/69)	2.4 (1931-35)	22.5 (1970-74)

1. RECORDED FLOWS - NATURAL
2. RECORDED FLOWS - REGULATED
3. COMPUTED FLOWS - NATURAL

* DISCONTINUOUS RECORD

A more significant regulation occurs downstream in Manitoba, at the Shellmouth Dam, which is used primarily as a flood control structure. At a recording site near Russell; downstream of Shellmouth, the mean annual flow is about 16 m^3/s, while at Brandon, it reaches about 30 m^3/s.

Water uses in the upper part of the basin are basically limited to agricultural needs, some of which are constrained by local supply and quality problems (Chapter VIII.3).

By agreement, Saskatchewan must provide 50 percent of the natural flow of the Qu'Appelle River to Manitoba. Recalling the statistics for the Qu'Appelle River near Welby (Table 37), half of the mean annual natural flow is about 3 m^3/s, while half of the lowest annual natural flow is about 0.1 m^3/s.

Between the Qu'Appelle River and the Souris, water requirements in the Assiniboine basin become greater. The largest are near Brandon, though supplies for domestic, local industrial, and a 237 MW thermal power plant are presently adequate. Regulation at the Shellmouth Dam has enabled maintanence of a minimum flow of 8.5 m^3/s at Brandon as compared to the recorded natural minimum flow of about 0.2 m^3/s. Irrigation is expected to expand near Brandon, but present usage is mainly from ground water, and extensive demands from the river in this area are not yet foreseen. The proposed location of a potash mine near the Saskatchewan border in this basin has been announced. The precise quantities of water required and the most likely source have not yet been made known. Similar potash mines in Saskatchewan presently each consume less than 0.05 m^3/s.

The Souris River has been the subject of intensive national and international investigations of both water quantity and quality. For example, the Souris River Basin Study Board (SRBSB), involving the governments of Canada, Manitoba, and Saskatchewan, produced a comprehensive report for this basin in 1978. Included were a number of water management recommendations.

The major regulatory works in the Saskatchewan portion are a reservoir at Weyburn and the Boundary Dam which stores water on Long Creek for an 874 MW thermal power plant. A 65 MW thermal power plant is also located near Estevan. Recreation developments exist around the reservoirs and lakes in this part of the basin. Portions of the streams are also used for recreation, and some stretches are considered to have particular scenic value. Waterfowl areas include several lakes located in the eastern part near the Manitoba border.

The Souris River flow at the Saskatchewan-North Dakota boundary is highly variable, both seasonally and annually. By agreement, Saskatchewan must release 50 percent of natural flow across the international boundary at the crossing near Sherwood. The computed mean annual natural flow at Sherwood is about 3.4 m^3/s (1912-74). The recorded mean annual flow (1931-1979) was about 4.1 m^3/s, due in part to very high flows in 1975, 1976, and 1979. The lowest computed annual natural flow (up to 1974) was less than 0.1 m^3/s.

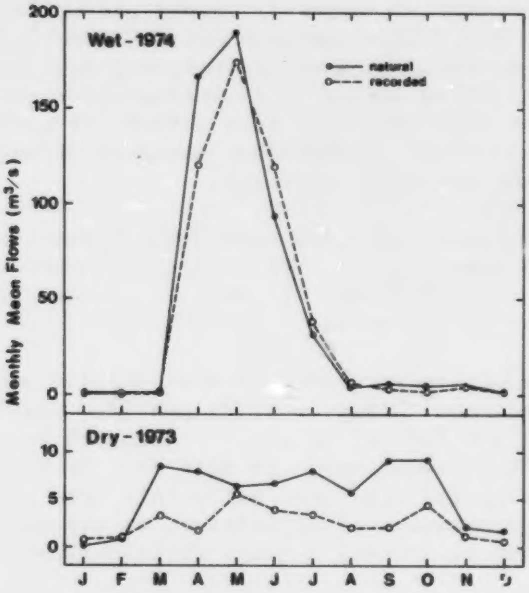
There is some irrigation in this part of the basin but soils are saline and water is in insufficient supply for extensive irrigation development. Other agricultural uses are severely constrained due to poor supply and water quality. Studies have been performed to determine ways of transferring water into this region from the South Saskatchewan River (Chapter II.2), but no specific proposal has been advanced by governments.

As part of a 1979 federal-provincial water development agreement, a new dam just downstream of the existing Weyburn Dam will be constructed. The new reservoir will store over 21 000 dam^3 of water and provide a dependable annual yield equivalent to about 0.12 m^3/s for municipal, industrial, and agricultural uses (Canada-Saskatchewan, 1979). Other water supply measures are being studied under this agreement, and some flood protection projects are included.

Within North Dakota, a number of other regulatory works affect flows in the Souris River. A proposed major diversion scheme associated with the Garrison Diversion Unit (GDU) (Chapter II.2) would return some of the water diverted from the Missouri River to the Souris. The GDU, if ever constructed as presently envisaged, is expected by the IJC (1977) to result in a substantial increase in the concentrations of most of the constituents that determine water quality in the Souris River. The GDU could result in an increase of as much as 300 percent in algae production. A concern relating to transfer of foreign biota into Canadian waters is discussed later under the Red River basin (Chapter IV.10).

On re-entry to Manitoba, the Souris River must have a minimum flow of 0.57 m^3/s from May through September, except under drought conditions. Between the boundary and its confluence with the Assiniboine, the Souris is regulated by a number of low dams for local supply purposes. A comparison of computed natural flow and actual flow statistics at one of these dam locations (Wawanesa) is made for a dry year and a wet year in Figure 57.

Figure 57. COMPARISON OF COMPUTED NATURAL FLOW AND RECORDED FLOW AT WAWANESA, FOR A DRY YEAR AND A WET YEAR.



The mean annual natural flow at Wawanesa is computed to be about 11 m^3/s. However, the smallest annual mean was about 0.3 m^3/s, and the largest about 43 m^3/s, illustrating again the great natural variability in this river. Flooding is a periodic problem for about 60 km north of the United States border.

Municipal requirements along the Souris in Manitoba are protected by the local impoundments and are not considered to be seriously threatened in the foreseeable future. Irrigation use is presently very small. Expansion is expected, though ground water locally may be the most common source.

Recreation developments in the Manitoba portion of the basin are associated with sites along the Souris River and at provincial park and recreational facilities. Major waterfowl areas exist at the Oak Lake-Plum Creek complex, which drains to the Souris River through Plum Creek, and Whitewater Lake, a shallow closed lake.

Although a firm supply is guaranteed to this part of the basin by international agreement, water quality is a concern, in part because of high dissolved solids and nutrient concentrations. In low-flow winter months, TDS values are particularly high and dissolved oxygen values are low.

The occurrence of twelve different pesticide residues in the Souris River drainage has been noted (Gummer, 1979). Some are found at relatively high concentrations, and four of the twelve have been detected only in this drainage region. Concern has been expressed about the long term effects of pesticides on fish, wildlife, waterfowl, and humans, although present environmental criteria are not yet being exceeded.

In dry years, botulism outbreaks in waterfowl have been of concern. In particular, Whitewater Lake, which is a major staging area for waterfowl, has suffered large losses of birds in the late summer of dry years.

On the Assiniboine River between Brandon and Winnipeg, the Portage Diversion (Chapter II.2) provides regulation for flood control. Up to 700 m^3/s can be diverted to Lake Manitoba in severe flooding conditions. In this part of the basin, there is presently some irrigation, but mainly from ground water. Any significant expansion of irrigation, as may occur for vegetable production, will likely require additional surface supply from the river.

The 45,000 irrigated acres (18 000 ha) estimated by Manitoba Agriculture for the year 2000 would require about 5 m^3/s on the average through the irrigation season. In a dry year, this would require a high percentage of available flow. For example, in August 1981, the Assiniboine River near Brandon averaged just over 4 m^3/s, and just over 16 m^3/s near Portage la Prairie.

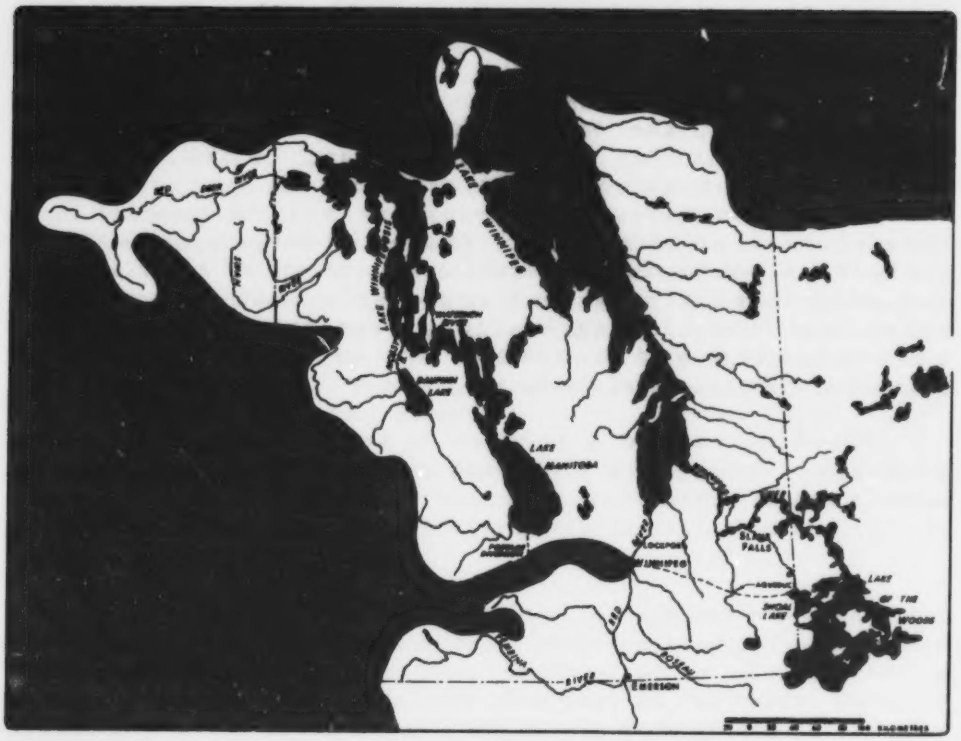
Under a 1980 Canada-Manitoba water development agreement,the possibility of enhanced water supply to the region south of the Assiniboine by a diversion from the Assiniboine River is being studied. Options under consideration are summarized in Chapter VIII.2. These include diversions southward from the Assiniboine River, possibly as far as near the United States border. Return flows would be to the Red River. Also under evaluation are additional storage works on the Assiniboine River, including a dam near Holland which would flood about 18,500 acres (7500 ha) upstream.

At Headingley, just upstream from where it joins the Red River, Assiniboine River flows have been recorded, and its natural flows have been computed (Table 39). The effects of present regulation are to increase winter flows and reduce flows in spring and early summer.

In summary, the Assiniboine River basin, including the Souris basin, lies in a region that, in dry years, is water-deficient and experiences water of poor quality. Industrial and municipal expansions are not expected to be limited by available water, though a large expansion of irrigation would require significant portions of river supplies and additional storage and conveyance works. Options for enhancing flows for agricultural and other uses in both Saskatchewan and Manitoba are under study within federal-provincial development programs.

Flooding can be a problem in several parts of the basin, although dyking, the Shellmouth Dam, and the Portage Diversion have increased protection.

Figure 58. THE RED RIVER/LAKE WINNIPEG BASIN.


LAKE WINNIPEG
LAKE WINNIPEGOSIS
LAKE MANITOBA
LAKE
LAKE OF THE WOODS
SHOAL LAKE
SLAVE FALLS
LOCKPORT
WINNIPEG
RED
RIVER
ROSEAU
PEMBINA
RIVER
EMERSON
KILOMETRES

10. RED RIVER/LAKE WINNIPEG BASIN

The Red River, the Winnipeg River, and the Lake Manitoba/Lake Winnipegosis complex all drain to Lake Winnipeg (Figure 58). Portions of these basins form the southeastern boundary of the Study Region.

The Red River and its international tributaries, the Pembina and the Roseau, drain over 100 000 km^2 in the United States before crossing into Manitoba. The Pembina River also drains 7500 km^2 before flowing southward to North Dakota and the Red River. En route to Lake Winnipeg, the Red River in flood stage can be partly diverted around the city of Winnipeg by the Red River Floodway. Supplemented by the Assiniboine, the Red River on entry to Lake Winnipeg drains an area exceeding 285 000 km^2.

The Winnipeg River enters Lake Winnipeg from the southeast. At Slave Falls, the river drains an area of almost 130 000 km^2, most of it in Ontario. In Manitoba the Whitemouth River is a major tributary draining the southeastern portion of the province.

Although linked by canal to the Assiniboine River since 1969, the Lake Winnipegosis/Lake Manitoba system essentially drains 78 000 km^2 of east-central Saskatchewan and west-central Manitoba. The two lakes are themselves linked by the Waterhen River, and drain to Lake Winnipeg via the Fairford River. Major tributaries to Lake Winnipegosis are the Red Deer and Swan rivers, and a number of rivers which flow to Dauphin Lake, thence to Lake Winnipegosis via the Mossy River.

Lake Winnipeg, with a surface area of 24 000 km^2, is a relatively shallow lake, having an average depth of 15 m. The southern basin, which receives the outflows of the Red and Winnipeg Rivers, is joined to the much larger northern basin by a narrow neck. The northern basin receives the outflow of the Saskatchewan River, as well as the much smaller drainage from Lake Winnipegosis and Lake Manitoba. In total Lake Winnipeg receives the surface discharge of a combined surface area of over 985 000 km^2.

The outflow of Lake Winnipeg to the Nelson River basin is regulated for downstream hydro benefits, within limitations of lake levels established by the province. An interim license was issued in 1970 for this purpose.

Statistics of surface flow at key locations are contained in Table 40. These are described below, together with use information extracted from Chapter VIII, for each of the Red River, Winnipeg River, Lake Winnipegosis/Lake Manitoba, and Lake Winnipeg regions.

The Red River at Emerson has a mean annual flow of about 94 m^3/s. Although regulated in the United States, the Red has very high flows during April-June which can cause severe flooding in wet years. Low winter month flows have fallen below 0.1 m^3/s, although the lowest mean monthly value is about 20 m^3/s (February). A contribution to the Red comes from the Pembina River which discharges an average of about 7 m^3/s from its drainage region in Manitoba.

Water quality of the river at Emerson reflects drainage from agricultural lands, with high values of suspended sediments and moderate concentrations of total dissolved solids.

TABLE 40. FLOW STATISTICS (m^3/s) FOR SELECTED POINTS - RED RIVER/LAKE WINNIPEG BASIN
(EC, 1980A; WER, 1980A)

RIVER	-	HYDROMETRIC STATION (PERIOD OF RECORD)	MEAN ANNUAL	LOWEST ANNUAL	HIGHEST ANNUAL	LOWEST MONTHLY	HIGHEST MONTHLY	MIN. 5-YR MEAN	MAX. 5-YR MEAN
RED	-	EMERSON[2] (1913-79)	94	9.4 (1934)	352 (1950)	0.03 (FEB/37)	2060 (MAY/50)		
		LOCKPORT[2] (1963-79)	238	51 (1977)	387 (1974)	19 (FEB/68)	2200 (MAY/79)		
		LOCKFORT[3] (1912-73)	168	37.6 (1931)	530 (1950)	3.7 (JAN/40)	3292 (MAY/50)	59.9 (1936-40)	275 (1966-70)
PEMBINA	-	WINDYGATES[2] (1962-79)	6.8	0.2 (1977)	20.8 (1974)	0 (MANY)	102 (MAY/74)		
WINNIPEG	-	SLAVE FALLS[2] (1907-79)	843	363 (1932)	1470 (1950)	312 (MAR/25)	2710 (JUNE/50)		
		SLAVE FALLS[3] (1912-75)	828	444 (1940)	1410 (1950)	294 (MAY/58)	2297 (JULY/50)	517 (1929-33)	1180 (1968-72)
FAIRFORD	-	FAIRFORD[2] (1913-79*)	81	1.8 (1964)	201 (1913)	0 (MANY)	330 (JUNE/79)		

1. RECORDED FLOWS - NATURAL
2. RECORDED FLOWS - REGULATED
3. COMPUTED FLOWS - NATURAL

* DISCONTINUOUS RECORD

Consumptive water uses from the Red River are not large compared to the supply. Irrigation (0.04 m^3/s in 1975), other agricultural uses, a thermal power plant, small industries, and small municipalities are not limited either by supply or quality. Foreseeable expansions of these uses also will not be constrained due to water requirements, though a possible major aluminum smelter just north of Winnipeg could require some process water.

Agricultural uses requiring local supply away from the river are presently affected by water quantity and quality problems. Soils to the west of the river are not well suited for irrigation. Farms and municipalities adjacent to the river suffer damage due to flooding, particularly in the upper part of the basin in Manitoba, where floods occur about once every four years. To the north, the Floodway now provides considerable protection for the city of Winnipeg.

The Red River is an important recreation source for local populations. The lower part of the river is the waterway most heavily fished for sport in Manitoba. Water quality presently affects recreation because of the often unpleasant nature of highly turbid waters, and the growth of weeds during periods of low flow. There is no indication that these problems will become significantly more severe due to foreseeable competing uses, although the growth of the city of Winnipeg could require additional treatment of its effluents to prevent more serious degradation downstream.

During low flow periods, transportation by the large recreation river-boats on the Red River can be seriously limited (Chapter VIII.9). In 1977, the situation was particularly bad when the annual mean flow fell to almost one-fifth the mean annual value.

Winnipeg does not withdraw its municipal supply from the Red River, taking it instead by aqueduct from Shoal Lake (Figure 58). In 1980 the city withdrew 97 million m^3 of water. This is expected to more than double by 2030. Future expansion alternatives include a second pipeline from Shoal Lake or a pipeline from the Winnipeg River (see Chapter VIII.5).

Some local industries in Winnipeg use ground water. No limitations due to overuse of this source have been identified or are predicted.

Treated effluent from Winnipeg is discharged to the Assiniboine and Red Rivers. The present volume in dry weather is about 110 million m^3 per year, with a projected increase by 1990 to about 145 million m^3.

The Red River at Lockport has a mean annual discharge of about 240 m^3/s. However, this figure is just for the period 1963-79. The computed natural flow (1912-73) is about 170 m^3/s.

The Winnipeg River is highly regulated for hydro power in Manitoba, though power generation (560 MW) does not appear to be in conflict with other uses. The mean annual discharge of the river at Slave Falls is about 850 m^3/s, with a relatively slight seasonal variation. The computed mean annual natural flow is about 830 m^3/s, demonstrating the effects of an upstream diversion into the basin (see Chapter II.2).

Although Winnipeg River drainage from the Shield region generally has a very good quality, concern has been felt about the effects of intensive recreation activities, feedlot operations, and pulpmill waste. A small nuclear research establishment exists on the river, but waste discharges are well within recommended levels. In Ontario there has been concern about the effects of mercury on fish and on native people who consume contaminated fish. The same source caused mercury contamination as far down the system as Lake Winnipeg, resulting in a temporary suspension of the commercial fishery on that lake during the mid 1970s.

Recreational opportunities are mainly in the Whiteshell Provincial Park, a 2700 km^2 area adjacent to the Manitoba - Ontario boundary. It is used extensively by the population of Winnipeg and other communities, and its waterways are increasingly subjected to waste effluents from townsites, campgrounds, and cottage developments.

The drainage of the Lake Winnipegosis/Lake Manitoba system to Lake Winnipeg is regulated by the Fairford Dam to control lake levels. The mean annual flow is about 80 m^3/s. This recorded value is about the same as the drainage to Lake Manitoba from Winnipegosis via the Waterhen River. This suggests that Lake Manitoba evaporates a volume of water similar to the volume it receives from precipitation and other drainage.

Lake Manitoba also receives inflow from the Assiniboine River via the Portage Diversion (Chapter IV.9). This varies considerably from year to year, and only occurs in the spring flood period. From 1970-1979, the mean annual diversion has been about 20 m^3/s. The IJC (1977) has suggested that some water quality parameters (e.g., nutrients, TDS) are increased in Lake Manitoba, while others (sodium, chlorate) are diluted, due to these diverted waters. Last (1981) has described the water quality of the lake, attributing its brackishness (especially in the southern basin) to evaporation, local drainage, and ground water inflows.

Water uses in this part of the basin include recreation, commercial and subsistence fishing, and agriculture. Some local supply problems exist where agricultural usage is at a distance from assured streamflows. Recreation consists mainly of waterfowl hunting and sports fishing. The Delta Waterfowl Refuge on the south shore of Lake Manitoba is an internationally recognized centre for waterfowl research.

Commercial and subsistence fishing information is summarized in Chapter VIII.8. Later in this section there is a discussion of the possible effects on the fishery of the Garrison Diversion Unit in North Dakota.

Because of the flatness of the land, flooding can be widespread in this region in wet years. The Swan and Whitemud Rivers, for examples, overflow frequently. Some instances of agriculture drainage have aggravated flooding in this region.

Lake Winnipeg is the drainage end point of this basin, and its outflow is to the Nelson River basin. The southern basin of Lake Winnipeg receives the discharge of the Red and Winnipeg Rivers, two quite different streams. The shores on the west side and the east side south of the Winnipeg River are popular recreation areas. They are mainly influenced by the highly turbid and poorer quality waters of the Red River. Beaches are often affected by algae. To the northeast, the waters are much clearer due to the effects of the Winnipeg River.

Sewage effluent from Winnipeg has been thought to be a significant contributor of nutrients to Lake Winnipeg. Although domestic and most industrial water is obtained elsewhere, the city discharges its effluents to the Red River. However, processes that affect the water quality character of Lake Winnipeg are not fully understood, due in part to the role of heavy loads of suspended substances (from the Red River and sediment movement due to waves and wind-generated currents) in limiting the growth of algae. A joint Canada-Manitoba committee at one time designed a thorough study of the problem under the Canada Water Act, but this has never been implemented. Consequently the need for nutrient removal from Winnipeg sewage has not been completely demonstrated.

Commercial fishing is a year-round industry in Lake Winnipeg. Fishing for subsistence is also of importance to natives. The fishery has been threatened by mercury from the Winnipeg River drainage, a problem now under active investigation, but the greatest threat is considered to be the proposed Garrison Diversion Unit (GDU) in North Dakota (Chapter II.2).

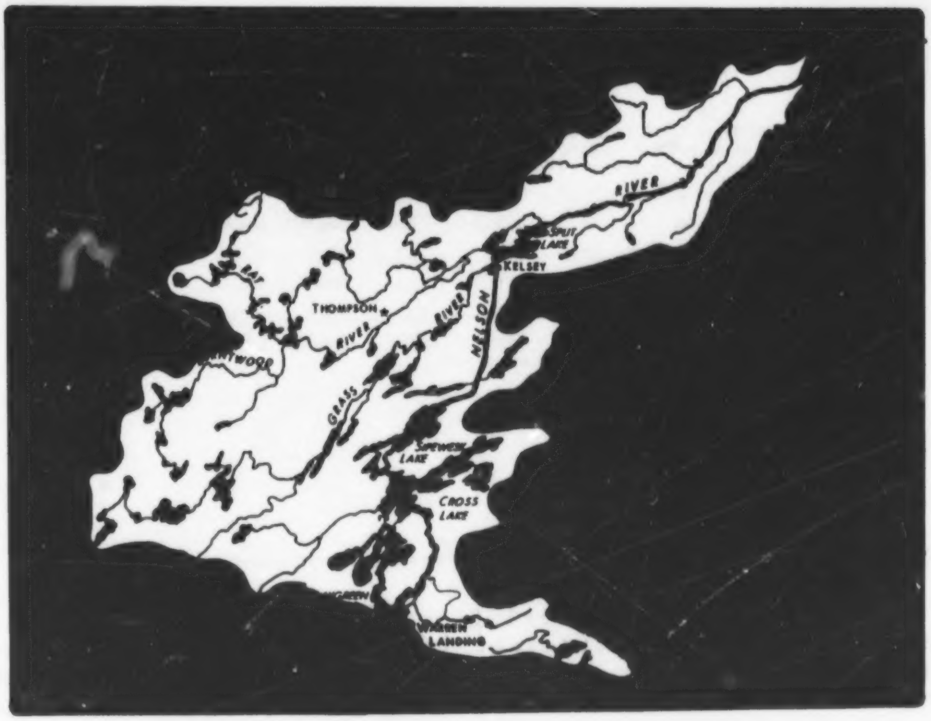
The GDU, if implemented, would increase flows to this basin via the Portage Diversion, the Assiniboine River, and the Red River. A study by the International Joint Commission (1977) concluded that increased flows would not severely aggravate flooding problems, that there could be some increased quality degradation, but that the most serious potential effect could be the introduction of harmful fish species and fish diseases to the Hudson Bay drainage. In May 1981, a moratorium on the project was supported by a United States court decision in favour of the Audubon Society, which has opposed the project. While uncertainty still exists about the eventual fate of the GDU, it continues to be opposed by the governments of Manitoba and Canada and by environmental groups in both countries.

The water levels of Lake Winnipeg are controlled to enhance hydro power production in the Nelson River. This can present a problem in wet years because of the threat of extensive flooding in the Red River delta and along the west shore of the lake. In addition to damage to inhabited and recreational lands, flooding can also present a problem for waterfowl habitat in the southern basin.

In summary, the Red River/Lake Winnipeg basin supports a variety of uses. Water is generally in sufficient supply, but is of quality which ranges from very good to marginal. Foreseeable municipal and industrial development are not expected to be constrained. Recreation, subsistence, and commercial fisheries will require additional protection from municipal and agricultural effluents, and are considered to be seriously threatened by the proposed Garrison Diversion Unit.

In low-supply years, local agriculture uses and transportation on the Red River are limited. In high-flow years, flooding continues to be a problem in the Red River south of Winnipeg and around Lake Winnipegosis, Lake Manitoba, and Lake Winnipeg.

Figure 59. THE NELSON RIVER BASIN


RIVER
SPLIT LAKE
KELSEY
RAT
THOMPSON
RIVER
RIVER
NELSON
NTWOOD
GRASS
SIPIWESK LAKE
CROSS LAKE
NGREEN
WARREN LANDING

11. NELSON RIVER BASIN

The Nelson River is the natural outflow of Lake Winnipeg, carrying to Hudson Bay the waters of the Saskatchewan River, the Red River, the Winnipeg River, and other streams flowing into Lake Winnipeg (Figure 59). A number of large lakes complicate the upper Nelson. Downstream the main stem is joined by the Grass and Burntwood Rivers from the west prior to its fairly straight run from Split Lake to its mouth.

The Nelson River is highly regulated for hydro power production (Chapter VIII.6). Discharge from Lake Winnipeg is controlled at the lower end of Playgreen Lake, subject to the provisions of an interim license issued in 1970. Before this control existed, flows through Playgreen Lake were often reduced by ice cover and weed growth.

TABLE 41. FLOW STATISTICS (m^3/s) FOR SELECTED POINTS - NELSON RIVER
(EC, 1980A; WER, 1980A)

RIVER	- HYDROMETRIC STATION (PERIOD OF RECORD)	MEAN ANNUAL	LOWEST ANNUAL	HIGHEST ANNUAL	LOWEST MONTHLY	HIGHEST MONTHLY	MIN. 5-YR MEAN	MAX. 5-YR MEAN
NELSON	- WARREN LANDING [3] (1912-73)	2050	932 (1941)	3046 (1966)	322 (JAN/41)	4967 (AUG/66)	1373 (1937-41)	2744 (1966-70)
	BELOW SIPIWESK LAKE [2] (1952-57)	2600	2300 (1957)	3020 (1955)	1500 (MAR/58)	3800 (JULY/55)		
	BELOW SIPIWESK LAKE [3] (1912-73)	2125	942 (1941)	3180 (1966)	368 (JAN/41)	5265 (SEPT/66)	1413 (1937-41)	2793 (1967-71)

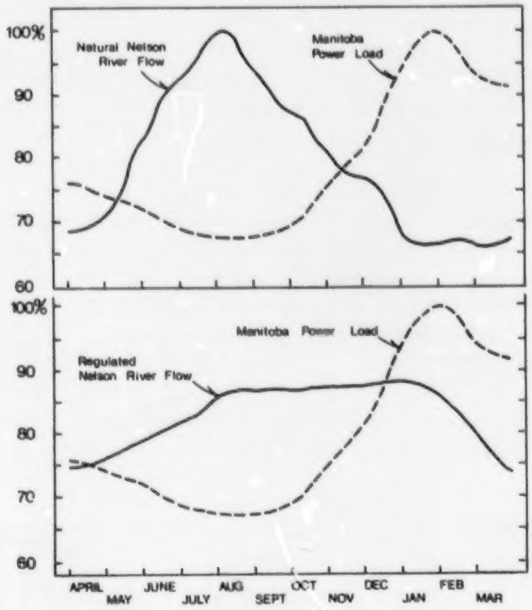
1. RECORDED FLOWS - NATURAL
2. RECORDED FLOWS - REGULATED
3. COMPUTED FLOWS - NATURAL

* DISCONTINUOUS RECORD

Statistics of natural flow at Warren Landing and below Sipiwesk Lake are contained in Table 41. Flow records on the upper Nelson River at these points for the period since the control was established are insufficient for a statistical comparison of natural and recorded flows. However, near the outlet of Cross Lake (Bladder Rapids), the recorded flow for the recent very dry year of 1977 was 1350 m^3/s. This value in comparison with the lowest annual natural flow below Sipiwesk Lake (942 m^3/s, in 1941) suggests that regulation may serve to maintain flow for hydro production during dry years. However, the main purpose of the Lake Winnipeg regulation is to alter the natural seasonal flow variation to follow more closely the pattern of power needs (see Figure 60).

Manitoba Hydro has identified ten hydro power development sites on the Nelson River, four of which have been constructed. The total estimated power production at full development is over 7600 MW. Six additional locations have been identified on the Rat River-Burntwood River diversion route from the Churchill River (Chapter II.2), with a total potential of 750 MW.

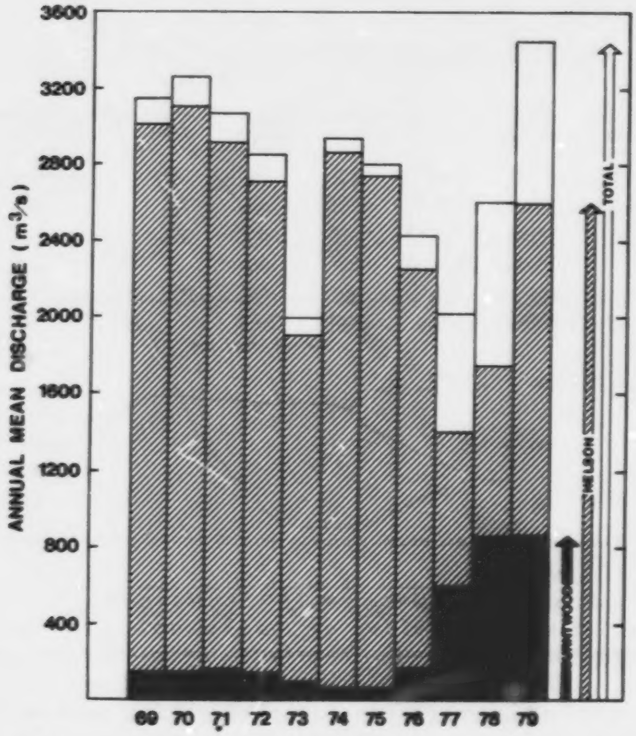
Figure 60. COMPARISON OF NATURAL AND REGULATED NELSON RIVER FLOWS WITH THE MANITOBA POWER LOAD (from Manitoba Hydro, 1977).



No hydrologic recording stations exist on the Nelson River below the confluence with the Burntwood. However, data exist just upstream on the Nelson at the Kelsey generating station, and on the Burntwood near Thompson, for the period 1969-79. These are used in Figure 60 to show how the contribution of the Burntwood has changed as a result of the diversion from the Churchill River, completed in 1976. The reader is reminded that the Nelson River was regulated throughout the entire period from 1969 to 1979, while the Burntwood was regulated only after 1973. During extended high-flow periods in the future, the total flow downstream of the Nelson-Burntwood confluence can be expected to be much higher than the 1979 total.

The present licensed diversion from the Churchill River is about 850 m^3/s provided that flows in the Churchill do not fall below specified levels (see Chapter II.2). Manitoba Hydro is considering requesting an increase in the licensed diversion during high-flow periods.

Figure 61. CHANGES IN THE CONTRIBUTION OF THE BURNTWOOD RIVER TO NELSON RIVER FLOWS, BEFORE AND FOLLOWING THE DIVERSION FROM CHURCHILL RIVER.



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The future development alternatives foreseen by Manitoba Hydro are described in Chapter VIII.6. Competing uses for water in this basin are those of the local inhabitants, and the interests of environmental conservation. A discussion of the effects of this development on the Churchill River system is contained in Chapter IV.12.

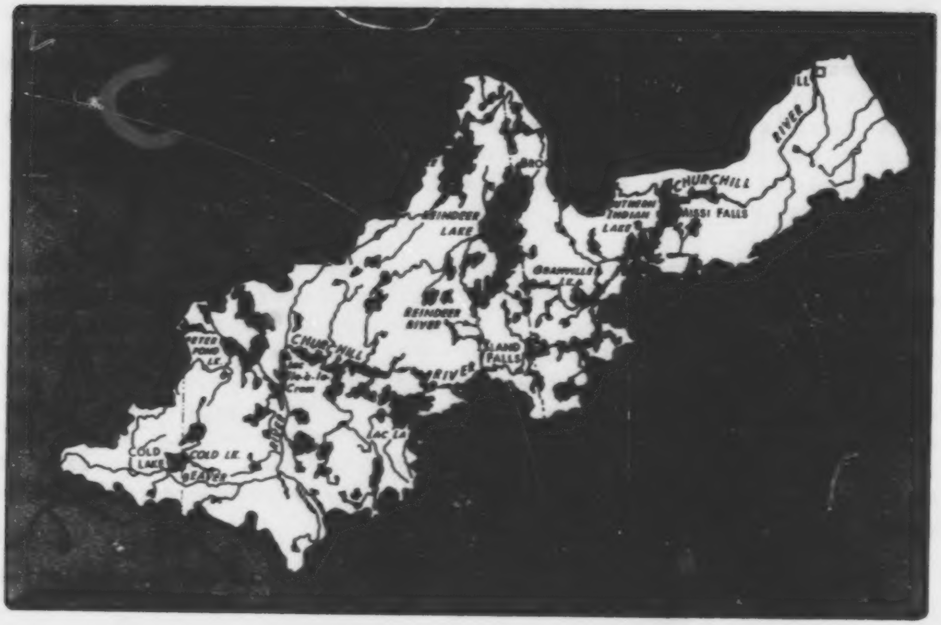
Newbury (1981) has used the example of the development of the Nelson River, including the Churchill-Nelson diversion, as a case of single-purpose development on a massive scale, with little or no prior evaluation of effects on the environment or other uses. Although those considerations might well be weighed in the future development of specific sites, the major component (the diversion) is committed. The long term effects of erosion and flooding remain to be seen. The possibility of flooding of native lands by future site development on the Burntwood River may require that priority be given to the construction of alternative sites on the Nelson River.

Some initial evaluations of water quality effects of the diversion have been made (e.g., Guilbault, R.A. et al, 1979). Mean levels of some parameters in the Burntwood have increased (e.g., total phosphorous, aluminum, and potassium) while others have decreased (e.g., calcium). The significance of these changes are not yet known.

Mining is another industry in this basin that can affect water quality. Contamination of surface waters by mine tailings has occurred locally, but has been prevented from reaching major drainage systems. Although atmospheric emissions from a smelter at Flin Flon have received more attention (Chapter IV.7), the emissions from Thompson are much higher at full production (Brown et al, 1981). Lakes in this region are sensitive to "acid rain" which can result from emissions of this type. The province of Manitoba is evaluating changes to its regulatory criteria in order to address the problem.

In summary, the Nelson River basin has a low population density and is not highly developed by industry, except for local mining activity. Transportation facilities are expanding so that increased development could be expected. An increase in recreation in the basin is likely. Resident populations hunt, fish, and trap for subsistence and recreation. However, the development of the river system has been principally for hydro power generation, and some present and foreseeable conflicts are evident.

Figure 62. THE CHURCHILL RIVER BASIN.


CHURCHILL
RIVER
SOUTHERN INDIAN LAKE
MISSI FALLS
REINDEER LAKE
GRANVILLE LK.
REINDEER RIVER
ISLAND FALLS
CHURCHILL
RIVER
PETER POND LK.
Lac Ile-a-la-Crosse
LAC LA
COLD LAKE
COLD LK.
BEAVER

12. CHURCHILL RIVER BASIN

Beginning with the Beaver River in Alberta, the Churchill River system includes portions of Alberta, Manitoba, and Saskatchewan (Figure 62). Its source waters begin in the Interior Plains, so do not exhibit the effects of mountain snow storage seen in many other basins in the Study Region.

The Beaver River flows eastward, then northward to Lac Ile-à-la-Crosse. From the north end of that lake, the Churchill River flows eastward through an intricate network of large lakes. In the eastern part of Saskatchewan it is joined from the north by the Reindeer River, which connects it to the 6650 km^2 Reindeer Lake. Crossing into Manitoba, the river again passes through several large lakes. At the southern end of Southern Indian Lake, a sizeable portion of its flow is diverted southward to the Nelson River system. The Churchill River then flows northeastward to its mouth at Churchill on Hudson Bay. The natural drainage area of the basin totals about 300 000 km^2.

Water uses in this basin vary considerably from one portion to another. For this reason, the review of supply and demand is best conducted in three segments: the Beaver River, the Churchill River in Saskatchewan, and the Churchill River in Manitoba. A discussion of uses for the entire basin can be found in Chapter VIII.

The Beaver River drainage basin, which in the recent past was primarily used for recreation and native uses, is developing as a centre for oil sands extraction. As the river flows eastward in Alberta, it passes to the south of a number of moderate sized lakes, including Cold Lake. These drain via the Waterhen River into the Beaver River some 200 km downstream from the Saskatchewan border. At the boundary, the presently unregulated flow of the Beaver River averages 27 m^3/s, with a lowest annual mean of 7.6 m^3/s in 1968. The lowest recorded monthly mean is 0.6 m^3/s. Table 42 contains a summary of hydrologic information for several key locations in the basin.

TABLE 42. FLOW STATISTICS (M^3/s) FOR SELECTED POINTS - CHURCHILL RIVER BASIN (EC, 1980A; WER, 1980A)

RIVER	- HYDROMETRIC STATION (PERIOD OF RECORD)	MEAN ANNUAL	LOWEST ANNUAL	HIGHEST ANNUAL	LOWEST MONTHLY	HIGHEST MONTHLY	MIN. 5-YR MEAN	MAX. 5-YR MEAN
BEAVER	- COLD LAKE RESERVE [1] (1956-79)	27	7.6 (1968)	61 (1962)	0.6 (FEB/64)	284 (JUNE/62)		
CHURCHILL	- OTTER RAPIDS [1] (1964-79)	332	148 (1968)	614 (1974)	129 (APR/68)	883 (AUG/74)		
	ISLAND FALLS [2] (1929-79)	705	317 (1941)	1060 (1932)	269 (MAR/38)	1620 (SEPT/32)		
	ISLAND FALLS [3] (1929-72)	682	402 (1941)	1080 (1932)	257 (MAR/41)	1584 (SEPT/32)	432 (1940-44)	936 (1931-35)
REINDEER	- OUTLET OF REINDEER LAKE [2] (1939-79)	322	155 (1957)	599 (1977)	0 (MANY)	859 (JULY/77)		

1. RECORDED FLOWS - NATURAL
2. RECORDED FLOWS - REGULATED
3. COMPUTED FLOWS - NATURAL

The river is unsuitable as a supply for any major consumptive use because of its small volume of flow. The flow of the Waterhen River is almost comparable to that of the Beaver, though the period of record is rather brief, and variations from year to year are also high. A portion of Beaver River flow (50 percent) is committed to Saskatchewan, as specified in the PPWB Master Agreement on Apportionment (1969).

The Cold Lake Oil Sands lie almost entirely within the Beaver River drainage, underlying a surface area of about 9000 km^2. Alberta is considering an application by Esso Resources to build a 25 400 m^3/d (140,000 B/d) plant which would require a one m^3/s supply of water. While a number of factors are involved, the water issue is an important part of the consideration for approval. In addition to the river, about 40 lakes exist in the region. Nevertheless, Alberta Environment has recommended that water from the North Saskatchewan River be the supply to the Esso project. This has been endorsed by the ERCB. A decision on the overall project has not yet been made.

Of the total water requirements for the Esso plant, 57 percent would be consumed in operation and the remainder disposed as waste. Some 0.15 m^3/s would be disposed in deep wells, with the remaining 0.3 m^3/s discharged to the Beaver River. Alberta Environment estimates that the effluent to the river will consume most of its assimilative capacity. The Prairie Provinces Water Board (1979) adopted a set of "Interim Water Quality Requirements" for the Beaver River at the interprovincial boundary and recommended their use for assessment of the effects of the Esso project. These "requirements" are designed specifically for Beaver River conditions. For some parameters, the requirements are less stringent than the PPWB water quality "objectives", recognizing that natural conditions are poor in some respects.

By early 1981, extensive studies of water quantity, including ground water, were underway by Alberta Environment. These were related in part to the Esso proposal, but also address the implications of future additional projects. It is difficult to predict the water requirements of future oil sands development (see Chapter VIII.4). However, assuming recycling, a development totalling 100 000 m^3/d production would require about four m^3/s. Because of the costs of water conveyance, studies were also underway by the industry to evaluate alternative local supplies, and to develop technology improvements aimed at reducing water needs. It is also conceivable that the Athabasca River basin could be considered as an alternative supply of water.

The prospects of extensive oil sands developments are of considerable concern to competing water users. Although local municipal requirements can be met, the impact of the development on local native economic and cultural needs and the effects on the extensive recreational water usage in the area have been noted. The substance of these concerns is found in proceedings of ERCB hearings held during 1979 and 1980. Alberta Environment has noted the following adverse impacts associated with oil sands development:

- increased sedimentation of water bodies during construction,
- disturbance of fish and wildlife habitat by construction activities,
- increased public access resulting in additional fish pressure,
- problems from atmospheric emissions of sulphur compounds, and
- environmental contamination from spills of waste materials.

These concerns are presently under investigation by that agency.

On the Saskatchewan side, there are concerns about the direct effects of large population increases on the Meadow Lake Provincial Park which extends from Cold Lake eastward along the Waterhen River. Saskatchewan is also concerned about potential contributions to air quality degradation and acid rain from plants in this region.

In the portion of the Churchill River basin between Lac Ile-à-la-Crosse (Figure 62) and the Manitoba boundary, municipal requirements are very small, and the only industrial withdrawal is for the Rabbit Lake uranium mine near Wollaston Lake (Chapter VIII.4). Very little industrial consumption of water occurs, and there are no present or foreseeable industrial or municipal constraints due to water supply. Nevertheless, the province of Saskatchewan has begun a review of the uses of water in the uranium mining industry. Of particular interest are the possible effects on local water quality of waste effluents.

The Saskatchewan Power Corporation has recently assumed control of this region's only hydro-electric plant, at Island Falls. The present installed capacity of the station is 107 MW. Live storage for this operation is provided by Reindeer Lake (18 million dam^3) via the Reindeer River, which contains a control structure. Because the lake is capable of controlling only a portion of the total Churchill River volume, operating options are limited.

Upstream of the outlet of Lac la Ronge (where there is a control structure), the Churchill River is unregulated. The mean annual flow at the Otter Rapids (due north of Lac la Ronge) location is about 330 m^3/s. At Island Falls, the recorded mean annual value is 705 m^3/s. The contribution from Reindeer River averages 322 m^3/s. A comparison of recorded data and computed natural monthly flows at Island Falls is contained in Table 42. The operation of the storage reservoir results in a smoothing out of the seasonal variation in flows.

Commercial and recreational fishing are important industries in northern Saskatchewan. The commercial fishery, though in a decline which is expected to continue, is still of importance to the economy of the region. The significance of the recreational fishery is less easily determined, but angling license sales in the province are growing rapidly, and access to northern lakes is dramatically increasing.

No water quantity issues that will significantly affect the fishery exist or are foreseen in this region. Water quality problems due to local developments are also unlikely in the foreseeable future, although there is some concern emerging about possible water quality effects of uranium mining. Although mercury in fish in this basin has also been a concern, all occurrences are considered to be natural (Murray, 1978). Acid rain is unquestionably the major quality concern for the future. It has been suggested that industrial emissions in both Alberta and Manitoba could increase to the extent where fish populations in northern Saskatchewan lakes would be endangered.

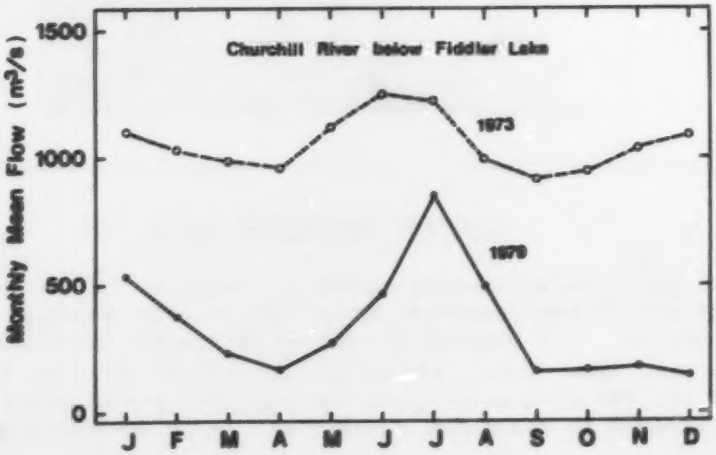
A proposed new hydro-electric dam (Wintego Dam) to be situated between the Reindeer River and the Island Falls Dam was the subject of extensive investigation in the mid-1970s. The Churchill River Board of Inquiry (1978) and the Saskatchewan Federation of Indians (1976) both produced reports on this issue. The latter concluded that there were no benefits and several disadvantages to northern natives from the proposed project. The Churchill Board of Inquiry, on the basis of this and other recommendations, decided that the hydro-electric project was not necessary (see Lennon, 1981).

In Manitoba, hydro power operations play a much greater role in the fate of the waters of this basin. A large diversion of water from the Churchill River at Southern Indian Lake to the Nelson River for hydro power production is described in detail in Chapters II.2 and IV.11. As an indication of the effects of this diversion on flows downstream of Southern Indian Lake, the average annual flow for the period 1968 to 1975 (inclusive) was 1150 m^3/s compared to an average of 435 m^3/s for 1978 and 1979.

The local effects of this diversion have been the subject of much controversy. The issues include local native livelihood and cultural factors, damage to the ecology and morphology of Southern Indian Lake, and effects on the environment in the diversion system (Burntwood River) and downstream in the Churchill River.

A full evaluation of the consequences of the diversion has yet to be made. However, a number of reports from studies by federal agencies are available. Among effects described thus far are increases in mercury in fish and decreases in the quality and quantity of commercial fish catches. Water quality changes have been noted since the diversion began in 1976, including increases in turbidity, colour, total inorganic carbon, phosphorous, hardness, calcium, and aluminum. However, no clear trend in effects of either the decreased flows or changing water quality has yet been established.

Figure 63. CHURCHILL RIVER FLOWS BEFORE AND AFTER THE DIVERSION TO THE NELSON RIVER.

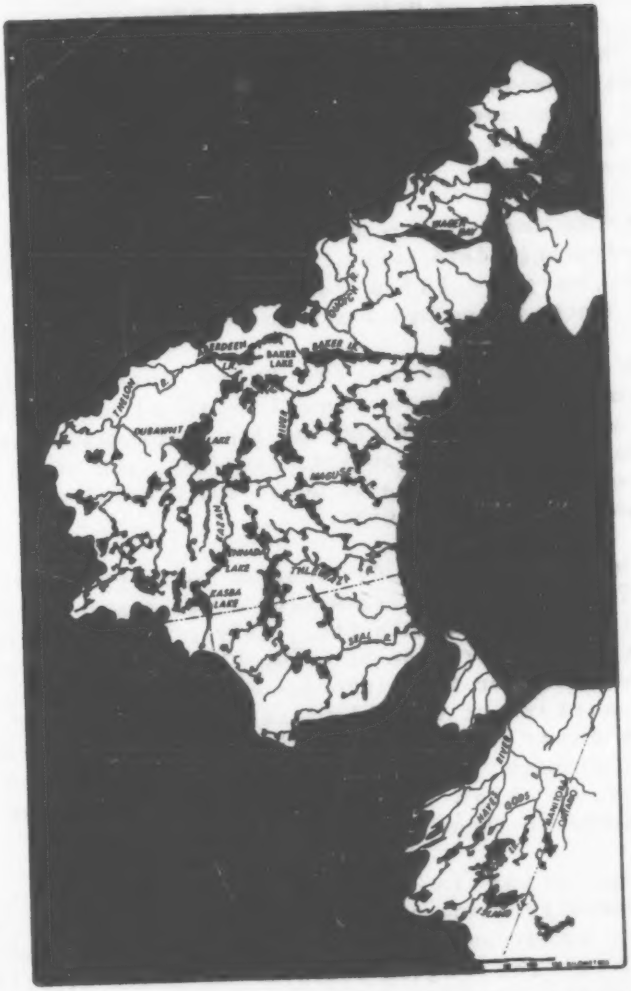


Newberry (1979) has used the Churchill River case to exemplify hydrologic and hydrogeologic consequences of major diversions. He and others have also noted the special circumstances of this example because of its location in a permafrost zone. The existence of permafrost results in a high degree of bank slumping and erosion under raised water conditions. Again, the actual long-term impact of this process remains to be seen.

The release of water to the lower Churchill downstream from Missi Falls is governed by license, which requires an outflow of at least 14 m^3/s during open water season, and 43 m^3/s during ice cover. The lowest monthly mean flow at Fidler Lake downstream of Missi Falls, recorded up to the end of 1979, was 147 m^3/s. The change in river flow since the diversion is somewhat illustrated in Figure 63 which compares 1972 with 1979.

In summary, the uses of water in the Churchill River basin vary substantially from its headwaters to its lower reaches. In Alberta, oil sands development could require transfer of water from other basins and water quality could become a serious concern. In Saskatchewan, the threat to the Canadian Shield waters by atmospheric emissions in Alberta and Saskatchewan is a major issue. In Manitoba, the effects of a large diversion to the Nelson River are of concern but have yet to be fully evaluated.

Figure 64. OTHER DRAINAGE TO HUDSON BAY.


WAGER BAY
QUOICH R.
ABERDEEN
BAKER LAKE
BAKER LK.
THELON R.
DUBAWNT LAKE
RIVER
MAGUSE R.
KAZAN
ENNADAI LAKE
THLEWIAZA R.
KASBA LAKE
SEAL R.
HAYES RIVER
GODS
MANITOBA
ONTARIO
ISLAND LK.

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13. OTHER HUDSON BAY DRAINAGE

A number of coastal drainage systems exist along the west coast of Hudson Bay, to the north, between, and to the south of the Churchill and Nelson River basins (Figure 64). In the north, the major system draining to Baker Lake, and then through Chesterfield Inlet to Hudson Bay, consists of the Thelon, Dubawnt, and Kazan Rivers. Both north and south of Chesterfield

Inlet, a large number of streams drain the coastal region. South and east of the Nelson River, the Hayes-Gods system and some smaller streams flow to Hudson Bay.

The Thelon-Dubawnt-Kazan drainage combines to produce a mean discharge of about 1200 m^3/s, approximately the same as the Churchill River system. The total drainage area is over 225 000 km^2, and includes some large lakes and a very large number of smaller lakes.

For those coastal streams north of the Churchill River, very little hydrologic data exist. Except for the Quoich River (mean annual discharge - 145 m^3/s) and the Seal River (348 m^3/s), only a few months of record exist for the streams in this region.

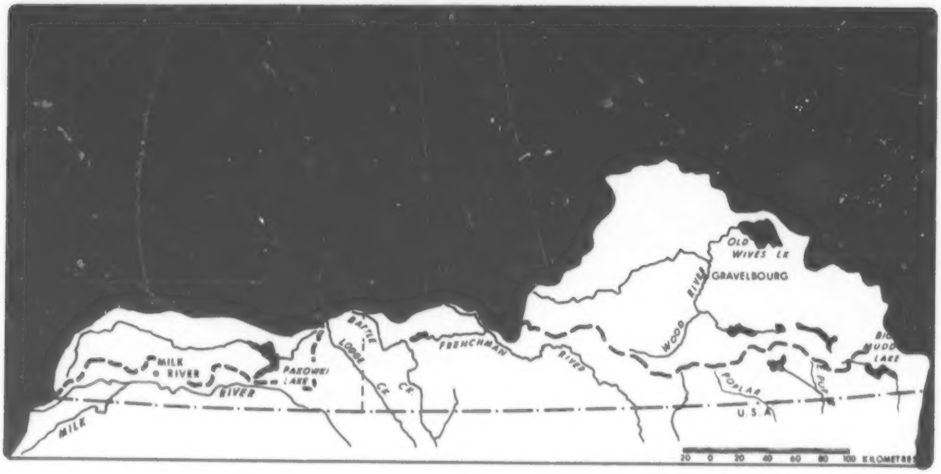
South of the Nelson, the Hayes River drains well over 100 000 km^2 with a mean annual flow of over 325 m^3/s. This region, including Gods River and its tributaries, is scenic and attractive for hunting, fishing, canoeing, and other recreation. Several large lakes (Island, Gods, and others) are found in the southerly portion of the region.

Four water quality study areas in this region were part of a program of environmental assessment of a proposed Arctic Islands Pipeline (Beak Consultants Ltd., 1979). These included an area adjacent to the west side of Baker Lake, a portion of the Kazan just south of Baker Lake, the drainage to the Maguse River, and the lower portion of the Thlewiaza River system. The report of that study described water quality as being "excellent" at all locations, though lakes are poorly buffered and susceptible to acidification. High turbidity can occur following occasional heavy rainstorms in these regions.

The population in this drainage region is not large, the largest community being at Baker Lake. Some mineral development exists, but water uses are small and are not in conflict at the present time. The region contains important wildlife habitat, including goose nesting and staging areas. The migratory Kaminuriak caribou herd is found in the southeastern part of the Northwest Territories and portions of eastern Saskatchewan and Manitoba. The potential for recreational fishing is great, though limited by lack of transportation facilities. Parks Canada has considered the Wager Bay region as a potential new park, but is presently not pursuing that possibility.

Future developments in this drainage region include two gold mines in the region between Ennadai Lake and the coast, expected to commence operations in the near future. There is also considerable active interest in the possibility of uranium mining developments at several locations within 200 km of Baker Lake (Chapter VIII.4). Studies of possible environmental and human health effects of this uranium mining are underway.

Figure 65. THE REGION DRAINING TO THE MISSOURI RIVER.


OLD WIVES LK
GRAVELBOURG
RIVER
WOOD
BIG MUDDY LAKE
FRENCHMAN
RIVER
BATTLE
LODGE
CR.
CR.
MILK
RIVER
PAKOWKI LAKE
RIVER
MILK
POPLAR
E. POP.
U.S.A.
20 0 20 40 60 80 100 KILOMETRES

14. MISSOURI RIVER BASIN

Drainage from a narrow land area across southeastern Alberta and southwestern Saskatchewan flows to the Missouri River in the United States, and thence to the Gulf of Mexico (Figure 65). The two largest rivers are the Milk and the Frenchman. Smaller streams include Lodge Creek, Battle Creek, Poplar River, East Poplar River, and Big Muddy River. Lodge and Battle Creeks are part of the Milk River drainage, joining the main stem in Montana. The total area drained is about 26 400 km^2.

The Milk River rises in Montana, flowing into Alberta, then back to Montana. An international agreement provides for guaranteed flows at both points. Similar agreements exist for several other streams crossing the international border in this drainage area.

The Old Wives Lake and Pakowki Lake closed drainage areas are included with the Missouri River basin in this report. The Old Wives Lake system totals 24 600 km^2 in area in south-central Saskatchewan. The Pakowki Lake closed drainage area, which lies just north of the Milk River basin, has a total area of about 5200 km^2.

The Milk River drainage basin in Alberta lies in a region of dry climate and uncertain water supply. Range development of a small number of large tracts of leased lands has occurred in this basin. A lack of intensive agricultural development here has led some to recognize the region as a wilderness area whose particular characteristics may be increasingly threatened by development. The Alberta Wilderness Association and other groups have urged measures to protect portions of the river valley. The province of Alberta has indicated an interest in the development of a comprehensive regional plan and has identified a 9100 hectare area as a candidate for Ecological Reserve status.

A report by Alberta Environment (1980b) describes water uses in the basin (Table 43) (see also Chapter VIII.2). Although this information is only for the Alberta portion of the Milk River basin, it serves as a useful recent summary.

TABLE 43. WATER USES IN THE ALBERTA PORTION OF THE MILK RIVER BASIN - 1979 (ALBERTA ENVIRONMENT, 1980B) (M^3/s)

USE	LICENSED	WITHDRAWAL	CONSUMPTION
MUNICIPAL (S)	0.02	0.02	[illegible]
IRRIGATION (S)	0.66	0.28	0.28
OTHER AGRICULTURE (S, G)	0.23	0.11	0.10
INDUSTRIAL (G)	----	0.001	0.001
TOTALS		0.41	0.38

S - SURFACE SUPPLY

G - GROUND WATER SUPPLY

Of a total surface water withdrawal of about 0.4 m^3/s, about one-quarter is provided by the Milk River. The rest comes from smaller tributaries. Because supplies are unreliable, about 700 small storage reservoirs have been established, which ensure a more reliable supply, but also result in increased evaporation losses, about 0.1 m^3/s annually.

Municipal and industrial uses are small and are unlikely to increase significantly. Agricultural uses are relatively large and depend substantially on local storage. Irrigation is the largest consumptive user (0.28 m^3/s, of which 0.09 m^3/s is drawn from the Milk River), although only about 70 percent of licensed withdrawal was used during 1979. There is considerable interest in expanding irrigation in this basin, but this is contingent upon assured supplies of water. Major expansion, to include the estimated 145,000 irrigable acres (60 000 ha) in this basin, is not possible with the water supply available in the basin.

TABLE 44. FLOW STATISTICS (M^3/S) FOR SELECTED POINTS - MISSOURI RIVER BASIN
(EC, 1980A; WER, 1980A)

RIVER	-	HYDROMETRIC STATION (PERIOD OF RECORD)	MEAN ANNUAL	LOWEST ANNUAL	HIGHEST ANNUAL	LOWEST MONTHLY	HIGHEST MONTHLY	MIN. 5-YR MEAN	MAX. 5-YR MEAN
MILK	-	MILK RIVER [2] (1912-79)	8.9	2.3 (1914)	13.8 (1953)	L 0.1 (MANY)	46.2 (JUNE/53)		
		MILK RIVER [3] (1912-74)	4.2	0.9 (1931)	10.3 (1951)	0 (MANY)	41.3 (JUNE/53)	1.8 (1937-41)	7.4 (1951-55)
FRENCHMAN	-	CAN.-U.S. BORDER [2] (1919-79**)	3.4	0.3 (1937)	20.5 (1952)	0 (MANY)	150 (APR/52)		
		CAN.-U.S. BORDER [3] (1912-74)	3.0	0.4 (1937)	14.5 (1952)	0 (MANY)	150.3 (APR/52)	1.2 (1933-37)	6.5 (1951-55)

1. RECORDED FLOWS - NATURAL
2. RECORDED FLOWS - REGULATED
3. COMPUTED FLOWS - NATURAL

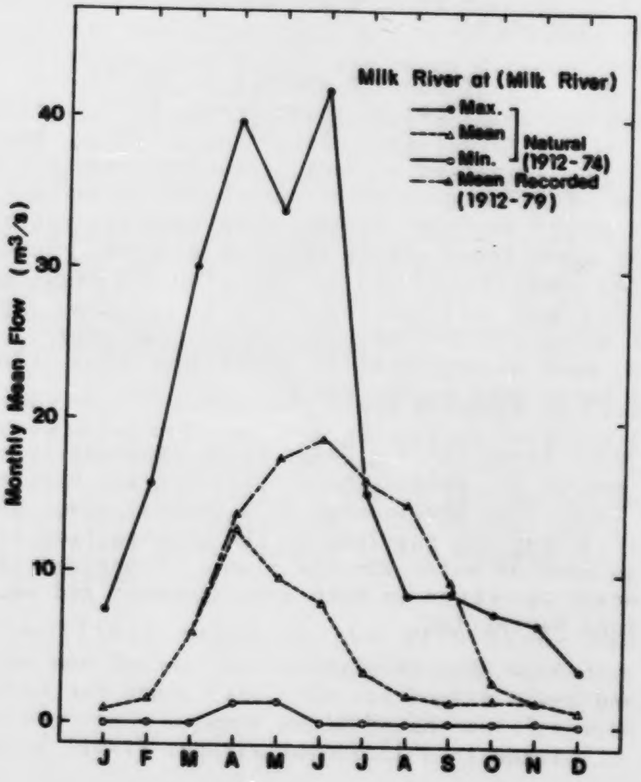
L = LESS THAN

** FOR PERIOD MARCH TO OCTOBER ONLY (AVERAGING OVER THE WHOLE YEAR WOULD LOWER THE ANNUAL VALUES BY ABOUT ONE-THIRD)

Statistics of surface water supply for the Milk River and other streams in this drainage region are contained in Table 44. Offstream uses along the Milk River are not usually limited by supply. Along with instream uses, they are provided some degree of protection by the international apportionment agreements. The Milk River flows are increased in the United States by diversion of the United States share of the St. Mary River apportionment. This water is transported through Canada in the Milk River for use back in Montana. While this water helps to assure minimum flows in Alberta, none of it can be consumed because it belongs to the United States. However, during 1977, when natural flows in the Milk River were very low, water used in Alberta exceeded the Canadian share. This was replaced by some of the Canadian share of the St. Mary River water, diverted through the same system to the Milk River.

Natural flows (maximum, mean, and minimum) computed for a location near Milk River, Alberta are compared with recorded flows at that point in Figure 66. The figure illustrates the effects of the apportionment arrangements. In the natural case, lowest monthly mean values in all but April and May are close to zero in value. Mean monthly values are below 2 m^3/s for seven months of the year. However, because of the water diverted to the Milk from the St. Mary River in Montana, the recorded values in this figure are much higher during April through October. Nevertheless, recorded monthly mean values in the winter can be very small (0.06 m^3/s, January, 1972). In a very low flow year, there can be supply problems for local municipal uses.

Figure 66. CHARACTERISTICS OF NATURAL AND RECORDED FLOWS IN THE MILK RIVER.



Comprehensive planning studies of various water supply alternatives in the Milk River basin were completed by Alberta Environment in February, 1981. Further socio-economic analyses were completed in April, and the construction of a dam just upstream of the town of Milk River was recommended. The Minister of Environment is likely to present his decision regarding development early in 1982, after observing reaction to the report. No changes to existing agreements with the United States are contemplated.

Supply problems are more severe in the tributaries, where storage facilities are widely used. In most cases, these streams are dry over the winter months. Alberta Environment (1980b) is studying the possibility of the development of ground-water resources as an alternative supply for the basin. The ECA (1979d) has indicated that there are problems of both overproduction and wastage of the Milk River aquifer.

To the east, the larger streams which drain to the Milk River from Alberta and Saskatchewan are also used primarily for agricultural purposes. Irrigation and other agricultural uses in the Lodge, Battle, Frenchman, and other basins are described in Chapter VIII.2. This portion of the basin also depends largely upon local storage works.

Water used for irrigation amounts to 28, 42, and 21 percent of the average annual flows of Lodge Creek, Battle Creek, and the Frenchman River, respectively (FitzGibbon, 1980). Water quality is marginal for irrigation in some instances, possibly due to the ground-water discharge which contributes to surface drainage. Irrigation could increase to make more complete use of Canada's share of the apportioned waters of these streams. However, there are not many opportunities to develop the required storage. Water quality and soil salinity effects are also a problem and may become more severe as development continues. Local water shortages and water quality problems also limit other agricultural water uses during dry years.

The Poplar River and Big Muddy River drainage is very small, and water supply and demand characteristics are similar to those just described. The development of a thermal power plant on the East Poplar River has resulted in the construction of a dam and reservoir to provide water for the plant. Concerns raised in the United States resulted in both apportionment and water quality recommendations by the IJC.

The IJC recommended measures to mitigate water quality effects and suggested procedures to compensate for possible damages. The Saskatchewan government approved the operation of a 600 MW plant. Any expansion of the present 600 MW facility would likely require diversion of water from elsewhere, possibly from Lake Diefenbaker. The maximum expansion could be to 1200 MW, though the Saskatchewan Power Corporation (SPC) has not announced a specific proposal for expansion.

Although the possibility exists for a similar international examination of the Big Muddy system, no reference has yet been made to the IJC by federal governments.

The Old Wives Lake internal drainage area lies on the northeastern side of the Missouri River drainage region. Water is a limiting factor for agriculture in this region. Present irrigation serves about 17,000 acres (7000 ha) and demands for irrigation water are increasing. While water supply is a constraint to further development, water quality and soil salinity are also problems in this region.

SPC has been considering the Wood River in the Old Wives Lake basin as a water source for a possible 1200 MW thermal power plant north of Gravelbourg. A dam and reservoir would be constructed on the Wood River, and water disposal from the plant would be to Old Wives Lake. There is a general concern that the Wood River does not have the capacity to meet SPC's requirements and all the water needs of the local community, particularly increased irrigation requirements by local farmers (SPC, 1981c).

Water users in the Pakowki Lake closed drainage area experience many of the same problems found in the Milk River basin. About 14,000 acres (5500 ha) are presently under irrigation. The area frequently experiences water shortages, particularly along tributary systems.

In summary, the Missouri River drainage in Canada includes several separate streams that experience very low flows in dry years. Municipal and industrial uses are small, and agricultural uses dominate, though they are widely limited due to low supply and poor water quality conditions. The thermal power development on the Poplar River is an example of the maximum utilization of a small prairie stream.

Use conflicts exist in the Milk River basin, where preservation may become increasingly at odds with development for agricultural and other uses. In the Poplar River basin, further thermal power development would be in conflict with downstream uses and would likely require importation of water.

PART C.

DRAINAGE TO THE ARCTIC OCEAN

CHAPTER V

WATER RESOURCES OF THE ARCTIC BASIN

1. HYDROLOGY OVERVIEW

A general comparison between waters of the Arctic drainage system and those of the southern basins is found in Chapter II.1. The surface drainage of the Mackenzie River basin portion of the Arctic drainage contains rivers of the three types (Cordillera, Interior Plains, Canadian Shield), whose characteristics have been described in Chapter II.1. Most of the other streams in the Arctic drainage originate on the Canadian Shield or in coastal lowlands.

Streamflow records for northern rivers are for locations that are more widely scattered than in the south and are usually for shorter periods of time. As a result, detailed statistics like those available for southern rivers are relatively rare. Considerable data do, however, exist for the major southern tributaries of the Mackenzie River. Hydrologic statistics for the following rivers are contained in Table 45:

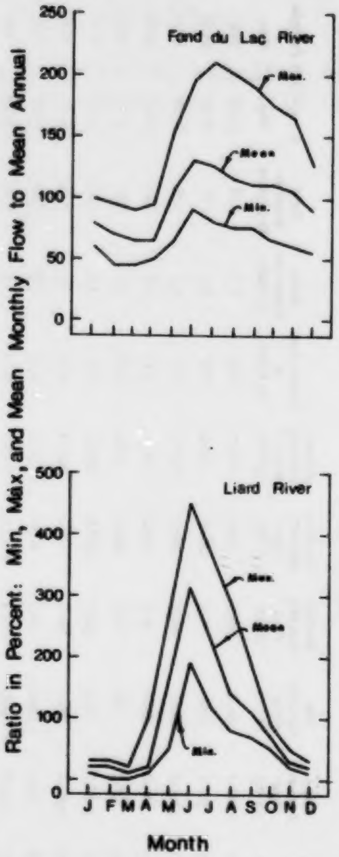
- Smoky
- Peace
- Athabasca
- Liard
- Fond du Lac
- Slave
- South Nahanni
- Mackenzie

The Fond du Lac River is an example of a Canadian Shield river in the Arctic system. Its ratio of maximum monthly mean to mean annual flow (Figure 67) is about two, compared to 4.5 for the Liard River, a Cordillera type. Such low ratios and low coefficients of variations indicate a relatively dependable flow throughout each year and from year to year.

Relatively few rivers originate on the Interior Plains. An examination of the records for the Hay, Wabasca, and other Interior Plains rivers, however, indicates that the ratios are generally smaller than those for the southern Interior Plains rivers. This is due to the more even distribution of precipitation and supply from snowmelt in the northern plains.

Three large Arctic rivers receive drainage from relatively major lakes: Fond du Lac River (Black Lake), Slave River (Lake Athabasca), and the Mackenzie River (Great Slave Lake). The effect of these lakes shows up in the relatively low ratios of mean annual to median monthly flow and maximum monthly mean to mean annual flow. These rivers have a more dependable flow from year to year and from month to month.

Figure 67. EXAMPLES OF FLOW-RATIO HYDROGRAPHS IN THE DRAINAGE TO THE ARCTIC OCEAN, USING COMPUTED NATURAL FLOWS (WER, 1980a).



Although they experience the greatest percentage of their annual flow on the average in June and July as do the other Arctic rivers, the percentages are smaller. The rivers having lake drainage experience from 11 to 17 percent of their annual flow on the average in the month of maximum flow, while the other rivers receive closer to 25 percent of their annual flow in the maximum month.

TABLE 45

HYDROMETRIC STATION NATURAL FLOW STATISTICS SUMMARY

(WER, 1980a)

Arctic Drainage	Period of Record	Mean Annual Flow (m³/s)	Max. Monthly Flow (m³/s)	Median Monthly Flow (m³/s)	Median Monthly Flow* (m³/s)	Median Monthly Flow** (m³/s)	Coefficient of Variation	Ratio¹ Maximum to Mean	Ratio² Mean to Median	5 Year Flow Periods		Month With Largest Per Cent of Annual Volume (%)
										Min.	Max.	
Peace River at Dunvegan Bridge	(1912-67)	1387.7	8815	188.5	782.3	1429.2	0.16	6.3	1.76	25-29	63-67	June (22)
Smoky River at Watino	(1913-73)	381.1	2898	19.1	204.1	466.8	0.27	8.3	1.77	37-41	63-67	June (23)
Peace River at Peace River	(1912-67)	1788.2	10855	199.0	1009.1	1916.1	0.17	6.2	1.75	25-29	62-66	June (28)
Athabasca River at Athabasca	(1912-73)	418.8	2000	49.4	289.9	581.5	0.22	6.0	1.44	37-41	62-66	June (25)
Fond Du Lac River at Outlet Black Lake	(1963-78)	300.3	631	147.5	286.0	328.5	0.18	2.1	1.06	N.A.	N.A.	July (11)
Slave River at Fitzgerald	(1921-78)	3523.7	7929	543.7	3624.6	4672.3	0.14	2.2	0.97	N.A.	N.A.	June & July (15)
Liard River at Fort Liard	(1958-78)	2001.4	9061	181.5	1418.7	2571.2	0.18	4.5	1.41	N.A.	N.A.	June (26)
South Nahanni River at Hot Springs	(1960-78)	428.9	2943	34.8	225.4	611.6	0.11	7.0	1.90	N.A.	N.A.	June (26)
MacKenzie River at Fort Simpson	(1938-78)	6758.7	18482	1581.4	8183.6	9656.1	0.10	2.9	0.82	N.A.	N.A.	June (17)

[1] Largest ratio of maximum monthly mean to mean annual.

[2] Ratio of mean annual flow to median monthly mean flow for historical period of record.

* For period March to October.

** For period April to October.

Only the Peace, Athabasca, and Smoky Rivers have periods of record long enough to develop a meaningful five-year moving mean analysis. For these rivers, the maximum five-year wet period occurred during the early 1960s with the historical low flows occurring in the late 1920s and 1930s.

Details of supply including specific hydrologic details for each individual basin are given later, in Chapter VI, along with the supply/demand analyses.

2. SURFACE WATER QUALITY

The most complete source of water quality data in this drainage region is a recent publication prepared for the Mackenzie River Basin Committee (Environment Canada, 1981). This federal and provincial data set will be the basis for a water quality interpretive report on the basin that will go beyond the brief summary below.

Population densities are low in this drainage region, so that sewage effluents are only of local concern. Industrial development in the Athabasca River basin and parts of the Peace River basin is growing but does not at present cause widespread quality degradation. Forestry and oil/gas exploration activities result in extensive soil erosion and consequent water quality degradation in southern portions. Specific water quality issues are described for each drainage basin in Chapter VI.

A 1977 overview of water quality in Canada (FEC, 1977) indicates that waters of the Mackenzie River basin are medium hard and somewhat turbid. The more recently published data (Environment Canada, 1981) indicate that TDS values in the Athabasca and Peace Rivers are less than 300 mg/L, with average values of about one-half that. Turbidity ranges from close to zero to several hundred JTU, with occasional very high values.

Land use activities in the upper and central reaches of the Athabasca and Peace Rivers have caused considerable erosion. The effects of these activities on water quality have caused some concern. Values recorded for total dissolved solids and turbidity, at several locations, are shown in Figures 68 and 69. Very high values for both parameters occur in the central part of the Athabasca basin, and high values for turbidity occur in the central part of the Peace River basin.

Included in the figures are values for dissolved sulphate for the Athabasca and Peace Rivers. The effects of pulp mill effluents, especially near Hinton, are evident.

Some of the northern tributaries of the Mackenzie River, from the west, have TDS values reaching 400-500 mg/L, while tributaries from the Shield region to the east have very low values. The main stem Slave and Mackenzie Rivers have low TDS values, but occasionally very high turbidity, reaching 1000 JTU.

Figure 68. RANGES OF CHEMICAL CONSTITUENT VALUES IN THE ATHABASCA RIVER: (a) total dissolved solids, (b) turbidity, and (c) dissolved sulphate (Environment Canada, 1981).

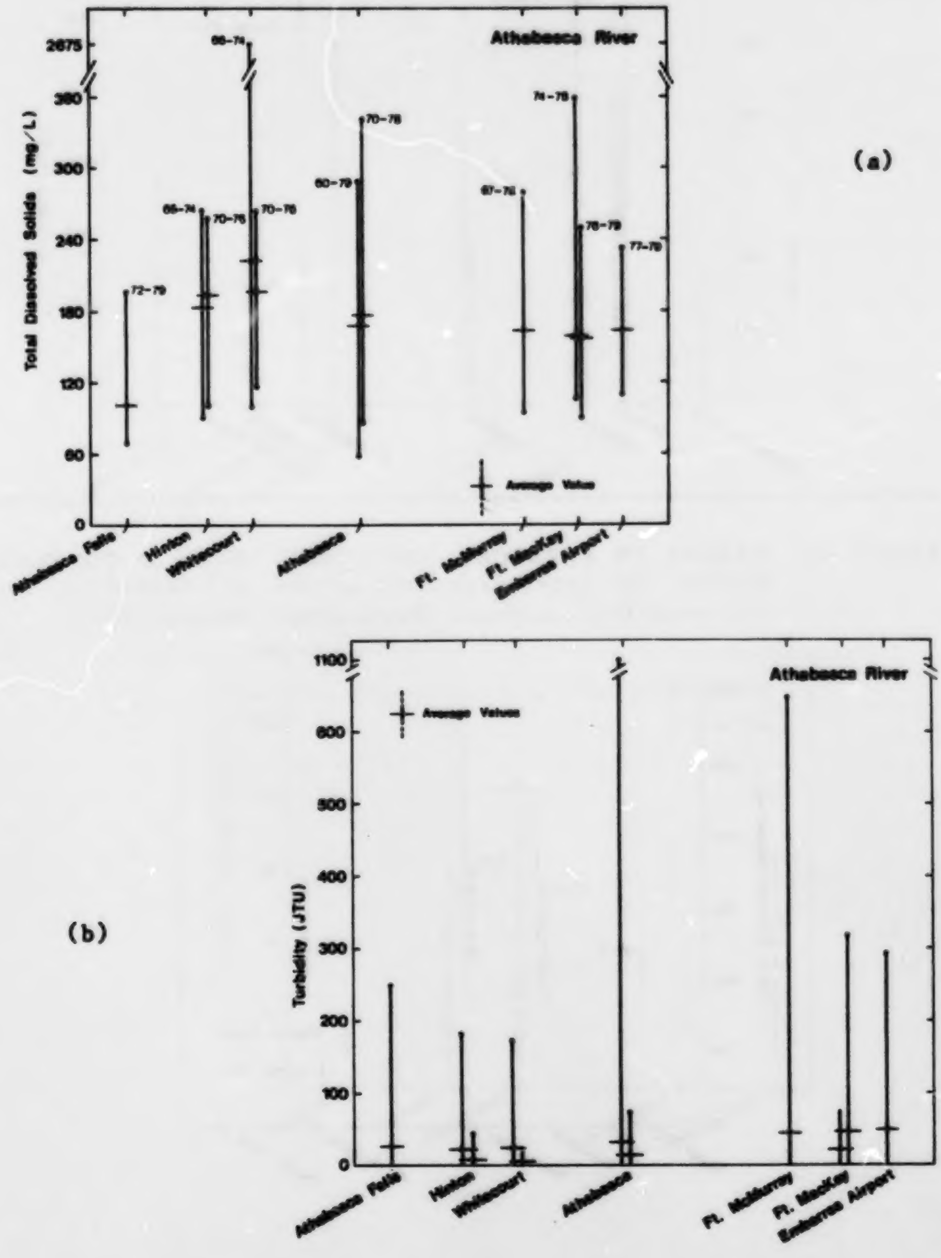


Figure 68. CONTINUED,
(c) dissolved sulphate, Athabasca River.

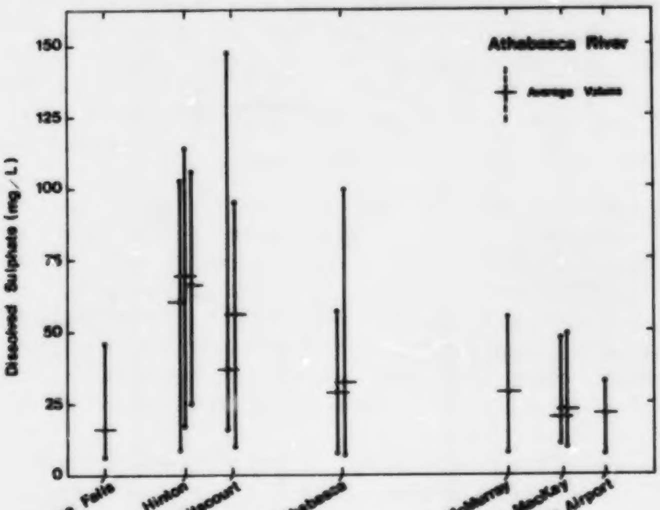


Figure 69. RANGES IN CHEMICAL CONSTITUENT VALUES IN THE PEACE RIVER (a) total dissolved solids (b) turbidity, and (c) dissolved sulphate (Environment Canada 1981).

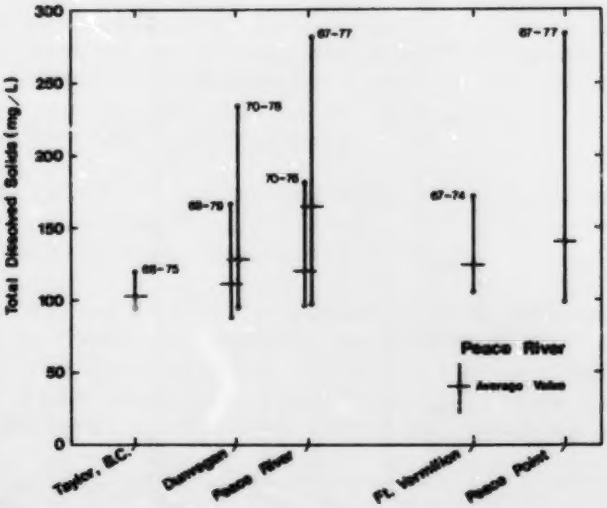
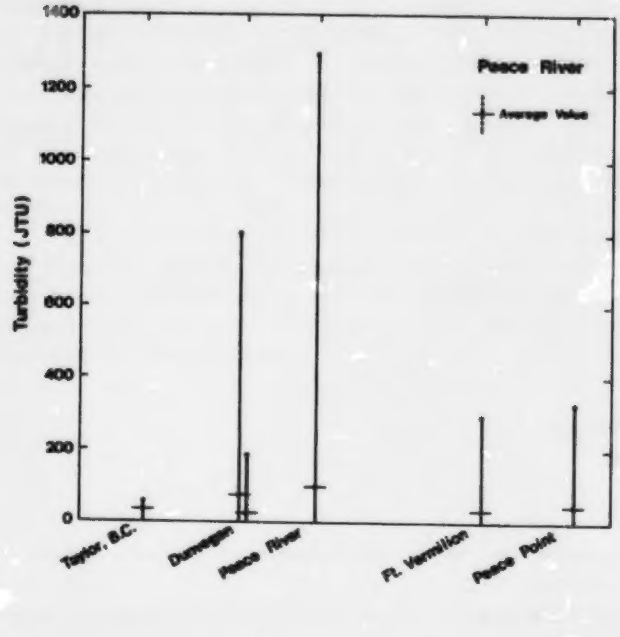
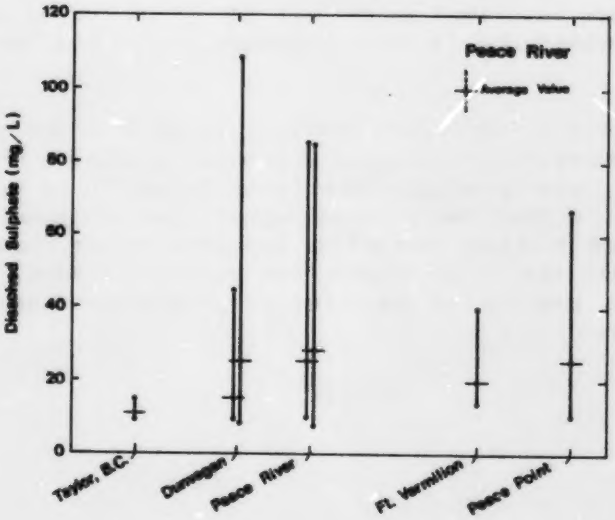


Figure 69. CONTINUED,
(b) turbidity, Peace River





(c)

TABLE 46. WATER QUALITY IN THE ARCTIC OCEAN DRAINAGE REGION (FEC, 1977)

RIVER	SPECIFIC CONDUCTANCE(1)	TURBIDITY (JTU)(2)	PH	TOTAL PHOSPHOROUS(3)
MACKENZIE (NORMAN WELLS)	231	12	7.9	0.007
LIARD (FT. SIMPSON)	266	36	8.0	0.030
PEACE (HUDSON HOPE)	185	2.3	7.9	L .005
COPPERMINE (MOUTH)	64	2.6	7.4	L .005

L = LESS THAN

(1) UNITS ARE MICRO SIEMENS PER CM

(2) JTU, JACKSON TURBIDITY UNIT

(3) MG/L

===

Values of pH in the Mackenzie basin range closely around 8.0, and dissolved oxygen values range approximately between 7 and 15 mg/L, with occasional lower values. Some specific local concerns relating to natural and artificial levels of certain metals are described in Chapter VI. Examples of median values of some parameters in this drainage region are contained in Table 46.

Waters in the other Arctic coastal drainage systems have not been extensively surveyed for their quality. Where data exist, however, the quality has been found to be very high. Human activities that could cause degradation are generally limited to scattered mining operations and some native communities. These basins all lie in the continuous permafrost zone, so that erosion problems can exist related to permafrost disturbance by human activities.

3. STANDING WATER

Lake waters in this drainage region are mostly components of the major drainage systems. There are no large closed basins, though some "prairie" style wetlands exist in southern portions. Numerous small Shield lakes exist east of the Mackenzie River and along the Arctic coastline. Almost 220 lakes larger than 100 km^3 in surface area have been identified in the Yukon and Northwest Territories (Environment Canada, 1973).

Great lakes in this region and some smaller lakes to the south have been developed for commercial fishing. Lakes in the Peace and Athabasca River basins provide a recreation base, though not as extensively as in the more populated basins draining to Hudson Bay.

4. GROUND WATER

A general description of ground water in the Study Region is given in Chapter II.4. The following contains more detailed information related to ground water in the Arctic Ocean drainage area. However, because ground water data for this area are generally limited, discussion is restricted to the Mackenzie River basin.

Information concerning ground water resources in the northern part of the Mackenzie basin is predominantly related to bedrock aquifers, since shallow ground water movement is inhibited by permafrost conditions. Surficial ground waters in the southern reaches of the drainage basin are similar to, and often continuous with, those of the adjacent Nelson and Churchill River drainage basins (Chapter III.4). Ground-water availability in the Mackenzie River basin in Alberta is shown in Figures 70 (bedrock aquifers) and 71 (surficial aquifers). The yields are those obtained by a variety of means, however, and may not accurately represent sustainable yields.

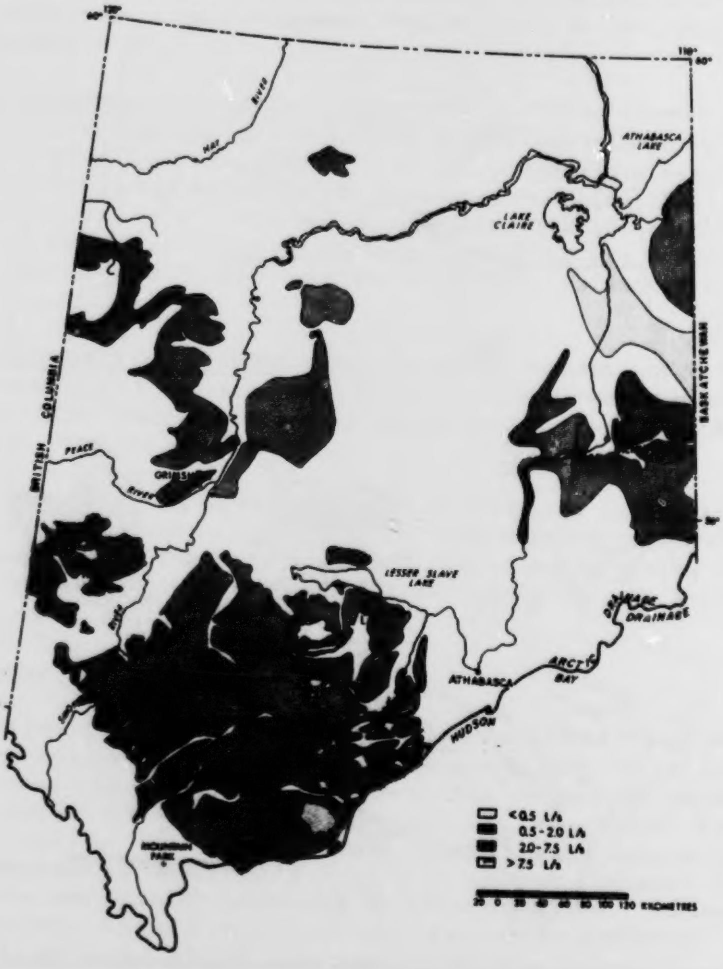
The great geologic variation throughout the Mackenzie basin is responsible for the diverse occurrence of ground water over that vast area. Each physiographic region has its own characteristic aquifer types and its own distinctly complex structure, stratigraphy, and geochemical make-up.

Considerable variation in surficial aquifers (aquifers associated with glacial deposits) may occur locally, but because virtually all of the basin was glaciated, regional variations are less pronounced. For instance, an intertill gravel in northern Saskatchewan may have very similar hydrologic properties to one in western Alberta, despite the very different bedrock terranes in those respective areas. However, regional changes in surficial aquifer hydrogeology become more pronounced when one compares areas classified as non-permafrost, discontinuous permafrost, and continuous permafrost.

Ground Water in Permafrost

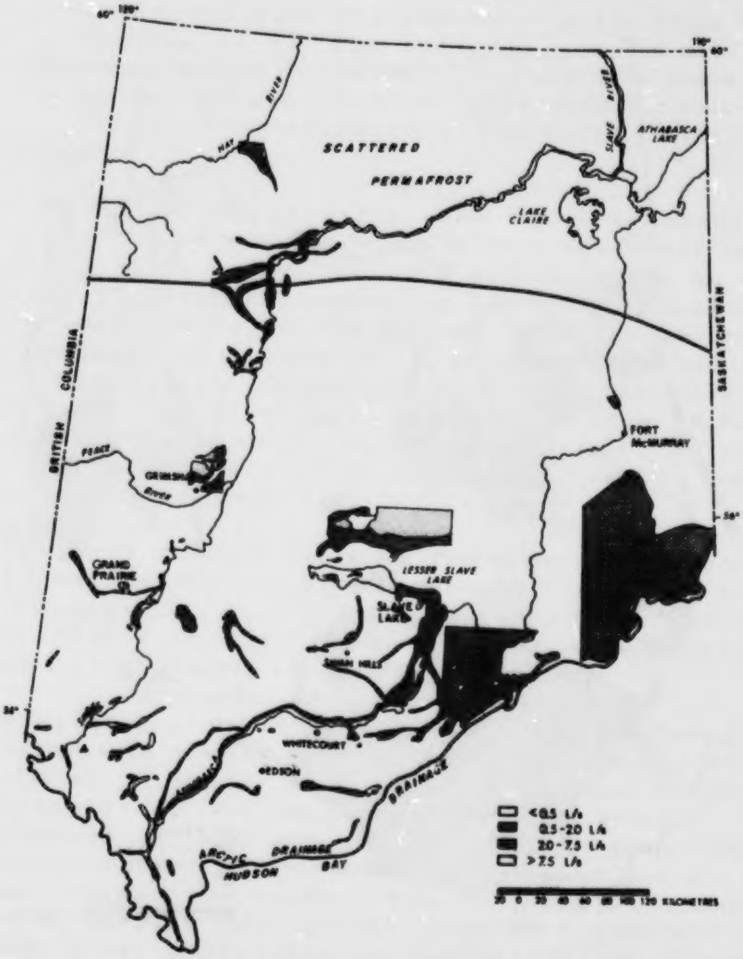
The available data on ground-water conditions in permafrost areas (Figure 71) are few, due to the high costs of exploration and a very low population density. Some data have been recently acquired, however, through the use of satellite imagery, particularly in the detection and study of cold and thermal springs, and icings or aufeis, caused by springs. Other indications of

Figure 70. LOCATION OF BEDROCK AQUIFERS IN ALBERTA, BENEATH THE MACKENZIE RIVER DRAINAGE BASIN (from MLM, 1981).


120°
60°
110°
60°
Hay River
ATHABASCA LAKE
LAKE CLAIRE
BRITISH COLUMBIA
PEACE River
GRIMSHAW
SASKATCHEWAN
LESSER SLAVE LAKE
56°
54°
ATHABASCA
ARCTIC BAY
HUDSON
DRAINAGE
MOUNTAIN PARK
<0.5 L/s
0.5-2.0 L/s
2.0-7.5 L/s
>7.5 L/s
20 0 20 40 60 80 100 120 KILOMETRES

the presence of ground water include the maintenance of open water stretches in some rivers, even during the coldest months, and the formation of topographically related features, such as icing mounds, frost blisters, icing blisters, and pingoes.

Figure 71. LOCATION OF SURFICIAL AQUIFERS IN ALBERTA, BENEATH THE MACKENZIE RIVER DRAINAGE BASIN (from MLM, 1981).


60° 120°
110° 60°
HAY RIVER
SCATTERED PERMAFROST
SLAVE RIVER
ATHABASCA LAKE
LAKE CLAIRE
BRITISH COLUMBIA
SASKATCHEWAN
PEACE RIVER
GRIMSHAW
FORT McMURRAY
56°
GRAND PRAIRIE
LESSER SLAVE LAKE
SLAVE LAKE
SWAN HILLS
54°
WHITECOURT
EDSON
ATHABASCA
DRAINAGE
ARCTIC DRAINAGE
HUDSON BAY
<0.5 L/s
0.5-2.0 L/s
2.0-7.5 L/s
>7.5 L/s
20 0 20 40 60 80 100 120 KILOMETRES

Discharge zones are identified by icings, by open water stretches in streams, and hydrochemically by an often appreciably higher dissolved solids content in stream waters, or the presence of halophytic ("salt-loving") plants near points of discharge. Recharge occurs only during periods when permafrost is melted, through temporarily unfrozen karst, or through the infiltration of lake or pond water through unfrozen materials underneath the body of water. The largest amount of recharge occurs in the late spring and early fall.

Three distinct types of occurrence have been identified for ground water in permafrost. Suprapermafrost ground water is found in thawed ground close to the surface, or underneath lakes and rivers, usually perched upon underlying frozen material. It can be used during the summer, but may not be available during winter months.

Intrapermafrost ground water exists within thawed zones of permanently frozen ground, sometimes called tabetisols or taliks. They generally form in alluvium that is in hydraulic contact with streams, or in glaciofluvial sediments covering the floors of wide river valleys. The degree of mineralization of the ground water varies, depending on whether the taliks are hydraulically connected to the upper active zone, or to deeper aquifers, possibly in bedrock.

Subpermafrost ground water is found beneath large areas of permafrost, and is often manifested in discharge from perennial springs. The mineral content of the water is frequently high due to passage through bedrock layers.

In summary, ground-water availability in the surficial aquifers of the sub-arctic is often seasonal due to the presence of permafrost. The only available ground water during freezing months in any given area may be from deeper bedrock aquifers or from perennial taliks.

Ground Water in the Canadian Shield

A major portion of the northeastern Mackenzie River drainage basin is occupied by crystalline bedrock that is structurally highly complex. Because most of this bedrock is impervious, ground water is restricted to joints, fractures, and fault systems, where the rock has been broken up and made permeable. The capacity is generally very low, however, because fracture zones are not usually pervasive or interconnected. Ground water data for the Shield are scarce, and it is difficult to make generalizations about the value of the resource in the crystalline basement complex.

Proterozoic sediments are found subcropping in the Lake Athabasca region, and in parts of the Northwest Territories northeast of the Mackenzie River drainage basin, east of Great Slave Lake. These sediments, which are often observed to be heavily silicified, are almost impervious. Ground-water flow can only occur through fractures, joints, partings, and shattered zones adjacent to faults. The overall fracture permeability of these zones may be quite high, but in comparison to the bulk volume of the rock, the amount of water held in storage is not expected to be very large.

The hydrogeology of the surficial sediments in the heavily glaciated Shield region has not been studied extensively, owing to the low population and the usual availability of good quality surface water. Low areas, which are characteristically poorly drained, are covered by thick layers of muskeg, peat, and other organic materials, and infiltrated water may be available from collector wells within these organic materials.

Good water supplies can be found in surficial materials where the sediments are sufficiently permeable and where natural drainage from these does not exceed input from atmospheric sources. Yields will probably vary from almost nil to greater than 8 L/s (0.008 m^3/s). This range has not been documented, but has been derived indirectly by the accumulation of data from other regions.

TABLE 47. MAJOR CRETACEOUS BEDROCK AQUIFERS IN THE INTERIOR PLAINS OF THE MACKENZIE RIVER BASIN (MLM, 1980)

FORMATION	ANTICIPATED WELLS YIELDS (L/s)	WATER QUALITY*
WAPITI	LE 2	TDS: 1000-2300 PPM $NAHCO_3$ AND NACL TYPES QUALITY DETERIORATES WITH DEPTH
GRAND RAPIDS	0.5 - 2	TDS G 1000 PPM (UP TO 300 000 PPM IN SOME AREAS) $NA-KHCO_3$ TYPES
DUNVEGAN	LE 8	TDS: 500-2000 PPM $NA_2-K_2SO_4$ AND $NA-KHCO_3$ TYPES
SHAFTSBURY	LE 2	TDS: 1000-2000 PPM $CA-MGSO_4$ TYPES (TDS G 2000 PPM AND $NA-KSO_4$ TYPES IN SOME AREAS)
PASKAPOO	LE 8	TDS: 500-1500 PPM $NAHCO_3$ AND $CA(HCO_3)_2$ TYPES

* NOTES

G = GREATER THAN
GE = GREATER THAN OR EQUAL TO
L = LESS THAN
LE = LESS THAN OR EQUAL TO
TDS= TOTAL DISSOLVED SOLIDS

Ground Water in the Interior Plains

Cretaceous bedrock formations (Table 47) contain significant aquifers throughout much of the southern part of the Mackenzie River basin. The Wapiti Formation is found throughout central and mid-western Alberta, and extends into northeastern B.C., past Dawson Creek, to the Cordillera. Water supplies are obtained from various sandstone and coal beds within the formation. The Grand Rapids Formation is a shoreline complex found in the Fort McMurray area of northern Alberta. The Dunvegan Formation subcrops in the Grimshaw area of northwestern Alberta. It may vary in thickness from 0 to 125 metres, but the aggregate thickness of aquifers within the formation is probably much less.

The Shaftsbury Formation subcrops in northwestern Alberta, northeastern British Columbia, the southern portion of the District of Mackenzie, and the Caribou mountains. Specific well yield data from this formation are somewhat scarce, however, due to the low population density. The Paskapoo Formation subcrops in a wide belt of the foothills throughout western Canada. Within the Mackenzie River basin, it is found from a line joining Drayton Valley and Mountain Park, Alberta, northeast to the Swan Hills, and northwest almost to the British Columbia border. Yields from aquifers in these formations are given in Table 47.

Paleozoic sediments are found within the Mackenzie River basin, but are restricted largely to a broad band that extends across northern Saskatchewan and northeastern Alberta, into the District of Mackenzie. Ground-water movement in these sediments has caused dissolution of the highly soluble minerals. Extensive dissolution of calcium and magnesium carbonate has also occurred along structural elements. Collapse of the rock strata is common and karstic terranes are formed. These terranes are distinguished by numerous sinkholes, the seasonal flooding of the sinkholes, disappearing streams, springs, and ground waters with a generally high degree of mineralization.

The Paleozoic sediments in the Great Slave Lake region contribute a considerable amount of ground water to the lake, generally via spring discharge. Saline springs are common, and waters are often warm and sulphurous. Flowing conditions have been noted over a large area south of Great Slave Lake, and some of the geographical names, such as "Saline River", "Sulphur Point", and "Salt River", attest to the quality of water from these artesian flow systems. Water in the rivers flowing into Great Slave Lake is often too highly mineralized to drink, which indicates that ground water base flow from Paleozoic sediments is very significant. Examples are the Little Buffalo, Salt, and Hay Rivers. The Slave River, which receives most of its ground water input from sediments to the east, is notably lower in dissolved mineral content than the Little Buffalo, which intercepts ground water from flow systems in the paleozoic sediments to the west.

Farther north, in the subarctic reaches of the Mackenzie basin, sulphur springs issue from the Cambrian shales of the Horn River and Fox Creek Formations, as well as from the Bear Rock Formation.

Although the development of solution channels, sinkholes, and karst in Paleozoic sediments may lead to quick infiltration of precipitation, the actual amount of water held in storage may not be correspondingly large, due to the low bulk porosity of the rock. However, it is probable that, where solution channels are well developed, up to 2 L/s may be available from wells completed in the sediments. In areas where fracture permeability is not well developed, less than 0.5 L/s can be expected.

Much of the Interior Plains portion of the Mackenzie basin is covered by surficial materials. In permafrost areas, however, these are of very limited hydrogeological value. Data on ground water availability and the extent of surficial aquifers in the northern part of the Mackenzie basin are scarce (Figure 71). MLM (1981) provides a list of communities that take ground water from surficial sediments, noting the source of supply.

In the Interior Plains occupying the southern reaches of the Mackenzie drainage basin, surficial aquifers may be classified in the same manner as has been done for the contiguous Nelson River drainage basin (Chapter III.4). Information is much more accurate for the southern plains than in the north, due to extensive studies conducted by the Alberta Research Council.

The most promising sources of ground water in surficial sediments in the southern plains portion of the Mackenzie basin are:

- buried preglacial valleys,
- glacial meltwater channel deposits and outwash sands,
- recent or Holocene alluvia.

The Edson preglacial valley, capable of yielding 17 L/s, extends from the Whitecourt-Edson area of Alberta to a point east of Lesser Slave Lake, and probably constitutes the most important surficial aquifer of its type in the Mackenzie basin.

Water yields of up to 40 L/s have been noted in some buried valley systems in northeastern Alberta, but maximum yields of only about 2 L/s are more commonly expected. Where these systems are in hydrologic contact with Paleozoic bedrock, their yield capacity may be considerably enhanced, due to the advanced state of karst development sometimes encountered in the upper bedrock. This increase in yield, however, is often achieved at the expense of water quality. Yields of less than 40 L/s may be expected from sand dunes and raised beaches. Intertill aquifers, while not known to produce large quantities of water in this region, often represent the only ground water source.

Near-surface outwash sands and gravels, such as deposits near Grimshaw, Alberta, may yield more than 40 L/s. Generally, however, these are not extensive and yields are expected to be less than 8 L/s. In the north-eastern portion of the province, where shales subcrop, ground water resources are very scanty, and surface water is usually used for domestic supplies.

Ground Water in the Cordillera

The occurrence of bedrock aquifers in this region of the Mackenzie River basin is dependent upon the development of fractures, joints, and faults within rocks of low permeability. In addition to physical forces, chemical forces are at work, causing accelerated rock dissolution.

Ground water yields over much of the Cordillera are unknown. Halstead (1967) states that the influx of ground water has forced abandonment of some underground and open pit mines in the Rockies, although very little difficulty has been encountered in other mines developed on actual fault zones.

The highest yields available are probably in carbonate rocks where the development of karst has occurred. Mildly deformed, fractured sandstones of the Paskapoo Formation occupying the eastern margin of the Rockies may yield from 2 to 8 L/s. Unfractured Paskapoo sediments are expected to yield less than 3 L/s.

Very little data is available on ground water in the Yukon Territory. In the north, ERTS-1 satellite imagery has been used to identify perennial, numerous, and highly mineralized, thermal springs in that region. These are also present farther south, in the Liard basin. Thermal springs described by Brandon (1965) include:

- Roche qui Trempe a L'eau, N.W.T.
- Old Fort Island Spring, N.W.T.
- Clausen Creek, N.W.T.
- Liard River Crossing, B.C.
- Portage Brule Springs, B.C.
- along the Flat and Nahanni River valleys

The entire Cordillera was glaciated during the Pleistocene Epoch, and the decay of the ice sheets caused a large-scale erosion, deposition, reworking, and redeposition process. For this reason many of the glacially eroded and over-deepened mountain valleys were filled with drift, interspersed and often overlain with outwash layers of variable thickness. Large volumes of meltwater loaded with debris spread outwash sands and gravels over wide areas. These glacial sediments, which may be very thick (up to 400 metres in some valleys) constitute important surficial aquifers that are readily recharged and usually contain water of very good quality. Although they are not as extensive as those in the plains, they generally exist beneath the only habitable lands in the Cordillera, the inter-montane valley floors, and may be very valuable sources of water. The yield of some of these aquifers is very high, as illustrated in Figure 71.

Water Quality

In the southern reaches of the Mackenzie Basin, the quality of ground water is subject to the governing factors discussed in Chapter III.4 of this report. Farther north, ground water chemistry is governed more strictly by the solubility of the aquifer materials, and less by factors such as length of flow path and residence time.

The quality of ground water in bedrock is to a large extent unknown for much of the basin. Some information concerning Cretaceous bedrock aquifers in the southern part of the Interior Plains is given in Table 47. Information about other bedrock aquifers, and surficial aquifers, is given below.

Water chemistry of the palezoic bedrock of the Interior Plains is strongly influenced by aquifer mineralogy because of the relatively high solubility of the evaporite and carbonate sediments. The presence of sulphur springs indicates that oxidation of sulphide minerals takes place. This in turn increases the chemical aggressiveness of the ground water by acidification, with a subsequent increase in the TDS content.

Where evaporitic salts are encountered, waters will be brackish to saline, due to the dissolution of such minerals as halite, gypsum, anhydrite, and carnallite. Where limestones and dolostones are encountered, the waters may be of the calcium-magnesium bicarbonate-sulphate type, where sulphur-bearing minerals have been dissolved along with the carbonate matrix. Gypsum dissolution will lead to calcium sulphate type waters, while halite dissolution will provide sodium and chloride. Potassium salts such as carnallite will contribute potassium, magnesium, and chloride.

Unless taken from extreme depths, ground waters within the Canadian Shield are generally of very good quality, with a TDS content of less than 400 ppm. The high quality of these waters is due to the relative insolubility of the rocks, the rapid rate of water movement through fracture zones in these rocks, and the short flow systems encountered. Most ground waters will be of the calcium-magnesium bicarbonate type.

Within the drift sediments that mantle the Shield, ground waters are likely to be predominantly of the calcium-magnesium bicarbonate type, and in areas of recharge or downward ground water flow, this water chemistry will be passed on to waters in underlying fractured bedrock.

Within the Cordillera and the Mackenzie lowlands, the chemistry of ground water is controlled mainly by the dissolution of carbonates, and to some extent evaporites. Thermal springs yield ground water that is frequently very highly mineralized, as a result of oxygenated waters having been in contact with soluble reduced minerals at great depth and high temperature.

Non-thermal waters, which flow from mountain highs to adjacent valleys via fractures, fault zones, joints and solution channels, will be less mineralized, and in carbonate terrane will be of the calcium-magnesium bicarbonate type. Waters in some fractured sediments will probably be of the calcium-magnesium sulphate-bicarbonate type, while in others, waters of very good quality can be expected.

The surficial deposits occupying mountain valleys will contain water of the calcium-magnesium bicarbonate type. In gravels the TDS content will be low, probably not above 1000 ppm. The very good water quality within these sediments can be attributed to high permeability and a short ground-water residence time.

Slightly higher mineral concentrations can be expected where surficial aquifers in valley bottoms are recharged from underlying bedrock springs. These springs may yield water which has had a very long residence time in the bedrock flow system, and has had ample opportunity to become saturated with respect to calcium and magnesium carbonate. Smooth, light coloured calcium carbonate deposits may be formed where these springs discharge onto the surface. Where spring outlets are buried beneath permeable glacial debris, the calcium carbonate will instead be deposited as an intergranular cementing agent in sands, or as a layered coating on pebbles and cobbles.

Effects of Human Activities

A description of the types of effects on ground water resources due to human activities is found in Chapter III.4. The level of these activities in the Mackenzie River basin is much less than in more southern basins, although local develoments could be significant. For example, mining of oil sands in the Fort McMurray area increasingly involves the dewatering of extensive excavations and the storage of waste waters in large holding ponds. Both activities have implications for the quality and quantity of local ground water regimes.

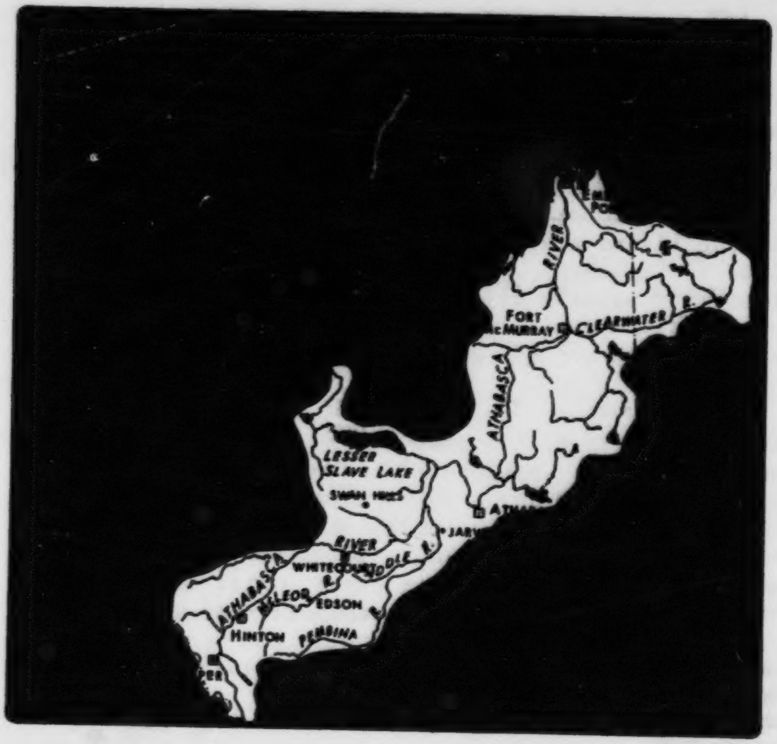
CHAPTER VI

ANALYSIS OF SUPPLY AND DEMAND - ARCTIC BASIN

1. INTRODUCTION

The following sections contain analyses of supply and demand for the basins of the Arctic drainage. The reader is referred back to Chapter II.1 for suggested precautions to be taken in the interpretation of these analyses.

Figure 72. THE ATHABASCA RIVER BASIN.


RIVER
FORT
McMURRAY
CLEARWATER
R.
ATHABASCA
LESSER
SLAVE LAKE
SWAN HILLS
ATHA
JARV
RIVER
WHITECOURT
R.
DLE R.
ATHABASCA
EDSON
HINTON
PEMBINA
PER

2. ATHABASCA RIVER BASIN

The Athabasca River rises high in the Columbia Ice Fields in the southern portion of Jasper National Park (Figure 72). After flowing northward through the Park, it bends northeastward and passes first through the forestry centre of Hinton, then the oil and gas field district near Whitecourt. At Whitecourt, it is joined by the McLeod River from the south. Northward, it receives the outflow from the Pembina River, then Lesser Slave Lake, before looping southward to the town of Athabasca. From there, the river turns northward again to Fort McMurray in the Athabasca Oil Sands region, where it is joined by the Clearwater River from the east. Continuing northward to its large delta on Lake Athabasca, the Athabasca River completes its drainage of 155 000 km^2.

TABLE 48. FLOW STATISTICS (m^3/s) FOR SELECTED POINTS - ATHABASCA RIVER BASIN
(EC, 1980a; MER, 1980a)

RIVER	-	HYDROMETRIC STATION (PERIOD OF RECORD)	MEAN ANNUAL	LOWEST ANNUAL	HIGHEST ANNUAL	LOWEST MONTHLY	HIGHEST MONTHLY	MIN. 5-YR MEAN	MAX. 5-YR MEAN
ATHABASCA	-	HINTON [1] (1962-79)	176	141 (1970)	213 (1965)	16.9 (MAR/63)	752 (JUNE/72)		
		ATHABASCA [1] (1914-79*)	436	299 (1919)	740 (1954)	49.2 (FEB/23)	2500 (MAY/48)		
		ATHABASCA [3] (1912-73)	417	277 (1939)	740 (1954)	49.2 (FEB/23)	2500 (MAY/48)	329 (1937-41)	491 (1962-66)
		EMBARRAS AIRPORT [1] (1971-79*)	783	749 (1972)	813 (1973)	134 (FEB/72)	2790 (JULY/71)		
MCLEOD	-	WHITECOURT [1] (1968-79**)	69.2	33.2 (1975)	111 (1971)	2.3 (FEB/69)	304 (JULY/71)		
PEMBINA	-	JARVIE [1] (1957-79*)	38.6	15.2 (1968)	85.1 (1965)	0.7 (FEB/68)	321 (JULY/65)		
CLEARWATER	-	FORT MCMURRAY [1] (1931-79*)	137	92.4 (1968)	215 (1960)	33.4 (FEB/68)	488 (MAY/74)		

1. RECORDED FLOWS - NATURAL
2. RECORDED FLOWS - REGULATED
3. COMPUTED FLOWS - NATURAL

* DISCONTINUOUS RECORD

** FOR PERIOD MARCH TO OCTOBER INCLUSIVE

Specific water use information is contained in Chapter VIII. A summary of water supply information at selected locations is contained in Table 48. Water supply/demand discussions can be usefully organized by three regions: headwaters to Fort McMurray, Fort McMurray region, and Athabasca delta region.

Industrial water requirements in the upper regions are related to forestry, mining, and oil and gas developments. Forestry operations on and near the east slopes of the Rocky Mountains can affect the drainage in two ways. Forest clearing can increase the volume of runoff, and forestry operations can increase erosion. The latter increases the loading of dissolved and suspended materials to nearby streams. Estimates of these effects vary, but it seems likely that future forestry developments could result in more noticeable changes. Particular concern is felt about erosion in the Swan Hills region, where oil and gas operations have been the predominant cause. The Alberta Forestry Service is presently investigating the problem and carrying out reclamation work.

Pulp mill sites in operation in Hinton, and soon to be operating near Whitecourt, discharge wastes to the mainstream, causing local water quality problems. This is presently not a widespread effect because dilution can accommodate the Hinton effluent and is also expected to satisfactorily decrease the effects of discharge from the new mill. However, if additional large mills are planned, their cumulative effects will need to be evaluated. Water supply will not be a problem for future mill operations. The mean annual flow of the Athabasca River at Hinton is 176 m^3/s (Table 48).

Water supply also is not expected to become a problem for coal mining in this part of the basin. Substantial new coal mining is predicted, particularly in the McLeod River drainage. A remote possibility exists for the development of a coal slurry pipeline from this area, though no specific proposal has been made. Although it is not known how much water would be required, a United States consortium has recently been authorized to build a pipeline with a maximum capacity of one m^3/s to transport nearly 23 million tonnes of coal annually.

The Alberta Environment Conservation Authority (AECA, 1974), in reviewing the effects of coal mining on the environment, expressed concern that poor site selection and reclamation practices result in erosion of stream banks and deposition of materials harmful to fish habitat. From these and other concerns, the AECA recommended substantial restriction of further mining and greatly increased safeguards to protect river systems.

Oil and gas field developments found in several tributary watersheds constitute the largest consumptive water users in this part of the basin (Chapter VIII.4). Water use for oil field injection in 1979 amounted to about 0.8 m^3/s. The present ratio of surface to ground-water supply is about 10 to 1. Exploration is continuing in several locations, so that expansion is possible. However, as reserves of recoverable oil are depleted, the increasing volumes of water recovered with the oil will reduce the volume of fresh water needed for injection.

Water supply, either from surface or ground-water sources, is not expected to limit oil and gas development. In the Pembina

River region, because of its availability, ground water is the principal source of water for injection. The volume used in 1980 (416 000 m^3) accounted for 80 percent of total ground water used for this purpose in the Athabasca River basin.

Water quality concerns stem in part from contributions of gas plant atmospheric effluents to the general problem of "acid rain". Acid rain is not presently considered to be a problem in Alberta, although the cumulative effects of sources in this province are becoming of concern in Saskatchewan. The ECA found that sour gas developments present fewer environmental problems in Alberta than does coal burning.

Of greater concern are the cumulative effects of soil erosion due to land and vegetation disturbance. Erosion takes place primarily in the tributaries. By the time the Athabasca River reaches Fort McMurray, it carries about 14 million tonnes of sediment per year.

Agriculture is a significant industry in the Pembina River, Paddle River, and Lesser Slave Lake areas. Little irrigation takes place, and the major water supply problem in these areas relates to flooding, which also effects some communities. In the Lesser Slave Lake case, measures are being developed to control lake levels and protect adjacent lands from floods. A dam on the Paddle River is under construction as a means to reduce local flooding. Solutions have yet to be found for the Pembina River where existing dykes have proven to be inadequate. Elsewhere in this part of the basin, agriculture drainage projects have caused local flooding problems.

There are no hydro or thermal power developments in the Athabasca River basin. While the potential exists for hydro, foundation and bank characteristics make major dam construction expensive. Although coal deposits are plentiful, no proposals exist for future development of thermal power. However, two possible sites for thermal power plants have been identified, and these could be developed in the future.

Present municipal water withdrawals in this part of the basin totalled between 0.1 and 0.2 m^3/s in 1977. No present or foreseeable water supply constraints exist, even though demands will increase substantially. The centres of Hinton, Edson, Whitecourt, and Athabasca, in particular, are expected to grow rapidly. The mean annual flow in the Athabasca River at Athabasca is 436 m^3/s.

Water treatment is necessary for domestic use in some locations. This is presently not a problem, except for users of ground water, which often requires some form of treatment. In some cases, local water quality problems are present due to inadequately treated sewage effluent.

Recreation is an important water-related activity in this part of the basin. Federal and provincial parks offer generally good protection of water resources. Outside the parks, recreational opportunities for canoeing, hunting and fishing are plentiful. In general, water quantity or quality conditions are acceptable for these activities. The exceptions are those cases where local effluents or erosion threaten fish habitat, or where effluents cause aesthetic problems (water colour and odour).

In summary, the upper portion of the basin is the scene of a variety of growing water use activities. At present, and for the foreseeable future, water supply is sufficient and water quality problems are not substantial, except where erosion/sedimentation problems threaten fish habitat. Flooding and drainage problems require additional attention, but are unlikely to be aggravated by new industrial developments. Many of the issues in this part of the basin can be addressed through the development of appropriate land-use policies.

Downstream, in the Fort McMurray region, the most spectacular and significant industrial developments in the basin are the oil sands projects. Because the projects are major consumers of water, it is necessary to examine statistics of river supply at this point (Table 48).

Because the river is unregulated and there are no provisions for upstream storage, minimum monthly flow values are of more significance to continuous water users than are annual means. At Fort McMurray the period of record begins in the late 1950s, so that a lengthy statistical data base is not available. Between 1958 and 1979, the lowest monthly mean flow was about 110 m^3/s (February, 1959). Upstream at Athabasca, where flow data begins in 1913, the lowest monthly mean was for February 1923, where the value was 25 percent lower than the February 1959 value at that location. Assuming similar conditions at Fort McMurray, the adjusted lowest monthly mean becomes 83 m^3/s. A similar analysis of lowest annual flows results in an adjusted value of 400 m^3/s at Fort McMurray.

The oil sands projects, present and foreseeable, are described in Chapter VIII.4. Operational oil sands plants required about 2.4 m^3/s supply of water in 1979, more than half of which was consumed. The rate of development of new plants and numbers of plants in simultaneous operation are presently uncertain. New technology may reduce the rates of water consumption. For a level of production of one million barrels per day, water requirement estimates vary between 6 and 12 m^3/s. The high value amounts to about 15 percent of the lowest monthly mean flow of the Athabasca River at Fort McMurray.

The municipal needs of Fort McMurray are small relative to the supply available, although treatment facilities require expansion to accommodate present and foreseeable growth. As oil sands development grows, there will be increases in local municipal water requirements. These are expected to increase at a slower rate than the industrial water demand.

In addition to water supply, there are four other important water-related issues in this part of the basin. These are increasing electric power requirements, local ice-jamming in the river, atmospheric emissions (acid rain), and water quality.

If a large number of oil sands plants are in operation at the same time, power demands will become increasingly significant. A study by Atomic Energy of Canada has demonstrated the feasibility of using nuclear power to produce injection steam. No specific proposal for any nuclear power development has been made in Alberta, and it is more likely nearby hydro-electric development on the Slave River would be used. However, if a nuclear power plant were to be considered at some future date, water requirements for it would be high, with the possibility of large waste heat discharges in the return flow.

A major problem in this part of the basin is flooding due to ice-jams during river breakup. Because breakup on tributaries takes place at a different time than on the main stream, ice jamming occurs downstream from Fort McMurray and waters can back up and cause flooding in the community. A proposed control structure has been studied and is under review by Alberta Environment. Concern has been expressed (Smith, 1981) that a control structure could be damaging to fish migration and habitat.

Atmospheric emissions from oil sands plants contain compounds of sulphur and nitrogen. These are the ingredients that can produce acid rain. Lakes and rivers in most of Alberta are chemically safe from acid rain, except for those in the northeast corner of the province, in the Canadian Shield (Chapters II.4 and III.2). However, the Shield region in northern Saskatchewan is more extensive in area, and is usually downwind of the oil sands sources. Work by the Saskatchewan Research Council, the University of Saskatchewan, and the Saskatchewan Department of Fish and Wildlife has concluded that emissions from the Alberta sources, based on predicted increases in oil sands plants and no change to the rates of emission, could result in fish mortality in lakes in northern Saskatchewan.

Other water quality concerns due to oil sands operations include increased loading of sediments, wastes from production processes, and disposition of saline waters pumped from mine pits. As mentioned earlier, several upstream uses contribute to increasing sediment loads in the Athabasca River. Present oil sands operations contribute to this problem by perhaps 5 percent, although steps have been taken to try to control erosion in the Fort McMurray area. Acceleration in delta building at the river mouth, probably due to increases in upstream erosion, has been noted by Neill (1980).

Water quality effects are also becoming noticeable downstream of the oil sands. Nutrient concentrations are increasing, as are levels of total dissolved solids. Oil seepage into the river is a natural phenomenon, and it is possible that oil sands mining will increase this seepage as a result of accumulations of oil in effluent holding ponds.

The seepage of waste waters from holding ponds to the river is difficult to measure. This water contains wastes from processing and, in some cases, water pumped from mining areas for depressurization and dewatering. It can become highly saline due to evaporation and the high salinity of ground water pumped from the mines. There is a complex interrelationship between water in holding ponds, ground water, water pumped from mining areas, and water returned directly to the river. While water quality effects downstream at present do not appear to constrain uses, there is clearly a need to evaluate the entire water and chemical balance in the system, and develop estimates of future loadings to the river, according to foreseeable project expansions.

As new mines are developed and additional holding ponds are constructed, the possibility for a more catastrophic type of water contamination could increase. The failure of a holding pond dyke or the sudden flooding of a mine with saline ground water would result in serious water quality problems.

There are no significant offstream water uses in the parts of the basin downstream from the oil sands development. Nevertheless, this region is important for its fisheries, its native uses and the ecological significance of the Athabasca River delta. At present, upstream water consumption does not affect uses in this region. Those concerns that do exist are due to water quality effects.

Fish migrations in this part of the river are important to commercial operations and native harvests. Although some whitefish populations are contaminated by parasites, the extent to which the total fishery is affected is not known. Increasing sedimentation caused by forest removal, surface mining, and other changes in land use could harm spawning grounds in the lower part of the basin.

Extensive studies have been conducted, and are continuing, on the entire complex of the Peace-Athabasca delta. The major impetus for these studies was concern resulting from low flows experienced in the Peace River due to the construction of the W.A.C. Bennett Dam. The attention of those concerned about the Lake Athabasca complex has now shifted in part to the possible effects on the lake of developments in the Athabasca River basin. Additional comments on the Peace-Athabasca delta are contained in later chapters.

The Athabasca River contributes an average of about 775 m^3/s annually to Lake Athabasca. Monthly mean values of flow near the mouth ranged from about 135 m^3/s (February '72) to about 2800 m^3/s (July '71) between 1971 and 1979.

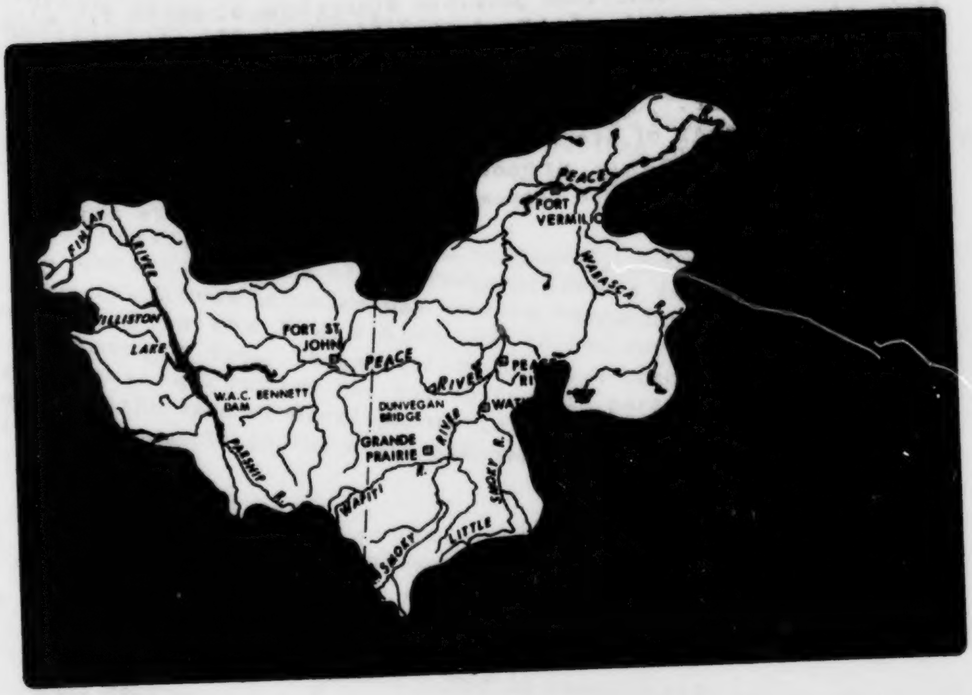
In summary, the Athabasca River is unregulated, except for some flood controls in tributaries. Present consumptive uses are small, but will increase as oil sands are developed. Local problems exist due to flooding, erosion, drainage, water supply, and water quality. These local problems are likely to become more severe as the basin experiences further development.

Water quality and sedimentation problems in the Athabasca River and major tributaries will probably increase with time. The extent to which these will adversely affect uses in the basin or in the Lake Athabasca complex is not yet known, but requires attention.

In the oil sands region, water quality could become the most significant water resource issue, both regarding local and downstream effects and regarding possible pollution of waters in Saskatchewan from acid rain. It should be noted that each new oil sands project has demonstrated new technological reductions in emissions of problem materials. Continued advances of this type could conceivably decrease concerns about future environmental effects.

There have been suggestions that diversions of water from this basin could be useful in drainage basins to the south. The SNBB (1972) has described possible diversions of up to 115 m^3/s from the upper part of the basin and about 285 m^3/s from the central part of the basin. The latter could be in conjunction with the diversion of an additional 560 m^3/s to the south from the Peace River. The net loss to the Athabasca River would be about 50 percent of its natural flow. None of these diversions has been specifically proposed. The economic and environment implications of such a proposal would clearly require thorough examination.

Figure 73. THE PEACE RIVER BASIN.


FINLAY
RIVER
WILLISTON
LAKE
W.A.C. BENNETT DAM
PARSNIP R.
FORT ST. JOHN
PEACE
RIVER
DUNVEGAN BRIDGE
GRANDE PRAIRIE
RIVER
WAPITI R.
SMOKY
LITTLE
SMOKY R.
PEA
RI
WAT
PEACE
FORT VERMILIO
WABASCA R.

3. PEACE RIVER BASIN

The Peace River system (Figure 73) drains an area of about 295 000 km^2 in British Columbia and Alberta. In the western portion, Williston Lake receives water from a number of large tributaries, including the Finlay and Parsnip Rivers. The lake, formed by the construction of the W.A.C. Bennett Dam in 1967, has a total storage volume of 70 million dam^3, over 17 times the size of Lake Diefenbaker.

The Peace River flows eastward into Alberta to the city of Peace River, where it is joined by the Smoky River from the south. It then moves northward to Fort Vermilion, before turning eastward toward Lake Athabasca. The mouth of the Peace River is an important element of the Peace-Athabasca delta at the southern end of the Slave River.

The primary use of the Peace River in British Columbia is hydro power generation at the W.A.C. Bennett Dam (Gordon M. Shrum plant) and just downstream at the Peace Canyon plant. A proposed new hydro site near Fort St. John (Site C) is presently under review, while a fourth site for possible future development has been identified near the Alberta border.

Site C will be the first major hydro-electric project in British Columbia to undergo public hearings in the new Energy Project Review Process. B.C. Hydro has identified several social and environmental effects to be expected if Site C is developed and has proposed mitigation and compensation measures. The project would flood prime agricultural land and there would be losses of wildlife and recreational opportunities.

Opposition to Site C (e.g., by the Peace Valley Environmental Association) is based in part on the social and environmental factors. There is also some disagreement with B.C. Hydro's projected energy demand growth rate (approximately 6 percent over the next 10 years). Some opponents feel that conservation measures would reduce the growth rate and postpone the need for further hydro development on the Peace River.

Coal mining in the southern part of the basin in British Columbia could result in local water quality effects. Although few public reports are presently available, recreation and local municipal supply are the most probable uses that could be affected.

The mean annual flow of the Peace River near the B.C.-Alberta border, as well as flow statistics for other locations in the basin, are contained in Table 49. The two provinces do not have any formal agreement regarding water quantity or quality at the border. The responsibility of the upstream jurisdiction has not been fully tested in law, although the legal implications of the effects of flow reductions of the Peace River in B.C. on Alberta users have been considered (Percy, 1980).

In Alberta, the Peace River and its tributaries serve many types of use. In general, present and foreseeable uses are not limited by water quantity or quality aspects. Local concerns do exist, however. These will spread, particularly in smaller tributaries, unless suitable precautions are taken. For example, municipal water supplies are not very secure because they depend upon the intermittent runoff of small drainage tributaries. Erosion and drainage problems have also been identified by Alberta Environment as priority items for management attention.

TABLE 49. FLOW STATISTICS (m^3/s) FOR SELECTED POINTS - PEACE RIVER BASIN
(EC, 1980A; WER, 1980A)

RIVER	- HYDROMETRIC STATION (PERIOD OF RECORD)	MEAN ANNUAL	LOWEST ANNUAL	HIGHEST ANNUAL	LOWEST MONTHLY	HIGHEST MONTHLY	MIN. 5-YR MEAN	MAX. 5-YR MEAN
PEACE	- DUNVEGAN BRIDGE[3] (1912-67)	1398	1007 (1945)	2082 (1964)	187 (DEC/52)	8815 (JUNE/64)	1201 (1925-29)	1727 (1963-67)
	PEACE RIVER[2] (1915-79*)	1780	904 (1968)	2680 (1964)	199 (MAR/19)	11000 (JUNE/64)		
	PEACE RIVER[3] (1912-67)	1768	1286 (1945)	2683 (1964)	199 (MAR/19)	10955 (JUNE/64)	1494 (1925-29)	2242 (1962-66)
	FT. VERMILION[2] (1915-78*)	2320	2160 (1962)	2620 (1964)	227 (FEB/16)	9700 (JUNE/64)		
SMOKY	- WATINO[1] (1915-79*)	371	219 (1361)	587 (1965)	22 (MAR/62)	1890 (MAY/20)		
	WATINO[3] (1912-73)	361	218 (1945)	731 (1954)	19 (FEB/37)	2996 (MAY/48)	275 (1937-41)	460 (1963-67)

1. RECORDED FLOWS - NATURAL
2. RECORDED FLOWS - REGULATED
3. COMPUTED FLOWS - NATURAL
* DISCONTINUOUS RECORD

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Generally increasing municipal, industrial, and recreational uses of water are foreseen in the river basin between Dunvegan and Peace River, and southward. A possible new development is a major hydro power plant near Dunvegan. The Dunvegan Dam is proposed for construction by about 2005. As a "run of the river" site, it is not expected to cause significant changes in downstream flows. Its reservoir will be long and narrow, extending to the B.C. border, possibly causing local environmental problems such as erosion and loss of wildlife habitat.

The Smoky River basin is a major tributary basin of the Peace River. It contains the city of Grande Prairie, a major pulp mill, a major thermal power plant, and several potential hydro sites. Fox Creek, in the southeastern portion, is a possible location for a new thermal power plant, but the water supply for it could be the Athabasca River. Water supply and quality issues are mainly related to local situations on smaller tributaries. For example, the largest industrial water consumption is by a pulp mill located on Wapiti River, a tributary of the

Smoky. In 1976, this plant withdrew 30 000 m^3 and consummed about 25 percent. This accounted for over three-quarters of the total industrial water consumption in the Alberta portion of the Peace River basin, which is very small compared to the local supply volume. This industry, however, has been the source of the most prominent water quality problem in the basin, particularly downstream at Peace River, where pulp mill wastes have affected water quality.

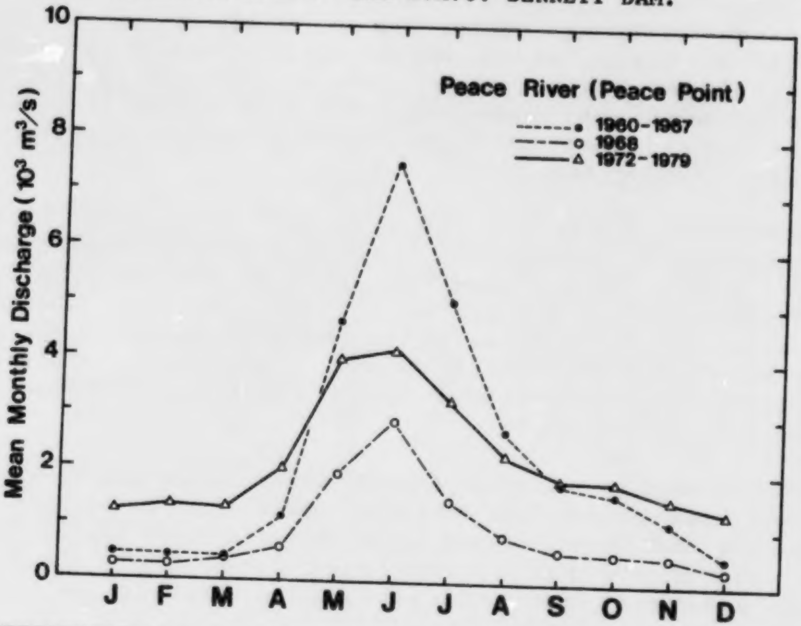
Immediately east of the town of Peace River lies an extensive oil sands deposit. It, and the Wabasca deposit in the Wabasca River basin (Figure 73), are being evaluated for future development. This development could result in substantial increases in water consumption and additional concerns about water quality. The estimated water requirement for plants in either of these deposit areas is about two m^3/s each (see Chapter VIII.4).

Downstream of the town of Peace River, water use development is even less extensive. Potential hydro sites exist both above and below Fort Vermilion and in the Wabasca River basin. At the lower end of the basin, the Peace River passes through the nation's largest national park, Wood Buffalo (see Chapter VIII.7).

The Peace River delta is part of the complex Peace-Athabasca delta. The delta was significantly affected by a reduction in the flow of the Peace River during the filling of the Williston Lake reservoir (1968-71). The damage to fish, waterfowl, wildlife, and vegetation has been widely documented (e.g., Peace-Athabasca Delta Project, 1972). The environmental and economic disruption received considerable attention and provided an example of the consequences of significantly altering the flows of a large river. With the restoration of normal mean annual flows, and the construction of works to restrict outflows from Lake Athabasca, conditions in the delta have returned to near normal (Smith, 1981).

An evaluation of the effects of Peace River regulation on Lake Athabasca has been completed by Alberta Environment (DeBoer, 1981). Seasonal flow patterns before and after the Williston Lake development are shown in Figure 74. Also shown is the pattern for 1968, the year of lowest flow during the filling of Williston Lake. Annual flows before, during, and after the reservoir development are approximately 2250, 900, and 2200 m^3/s, respectively. The smoothing out of seasonal variations by regulation is apparent in the figure. The construction of

Figure 74. FLOWS IN THE PEACE RIVER BEFORE, DURING, AND AFTER CONSTRUCTION OF THE W.A.C. BENNETT DAM.

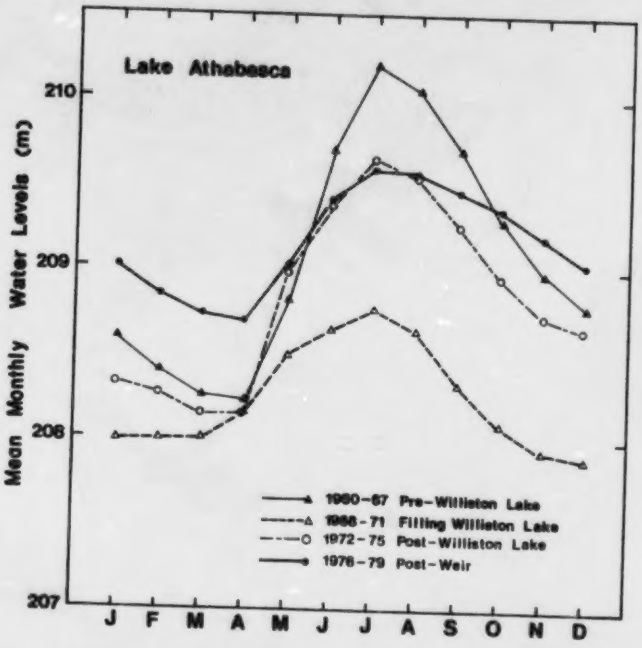


additional hydro sites on the Peace is not expected to significantly alter the flow pattern.

Variations in Lake Athabasca water levels are illustrated in Figure 75, for periods before construction of the Bennett Dam, during the filling of Williston Lake, during the return to full flows (regulated), and following the construction of a weir on Riviere des Rochers to control outflow from the delta and Lake Athabasca. The latter was necessary to correct decreased lake levels in the winter caused by the regulated flows of the Peace River (Environment Canada, 1981). The effects of the weir on lake levels are apparent in the figure. However, the lack of appropriate fish control structures impedes normal fish migration during low-flow periods (Smith, 1980).

In summary, the Peace River basin has been the scene of one of the most controversial water developments in Canadian history, where flow reduction for a hydro development temporarily resulted

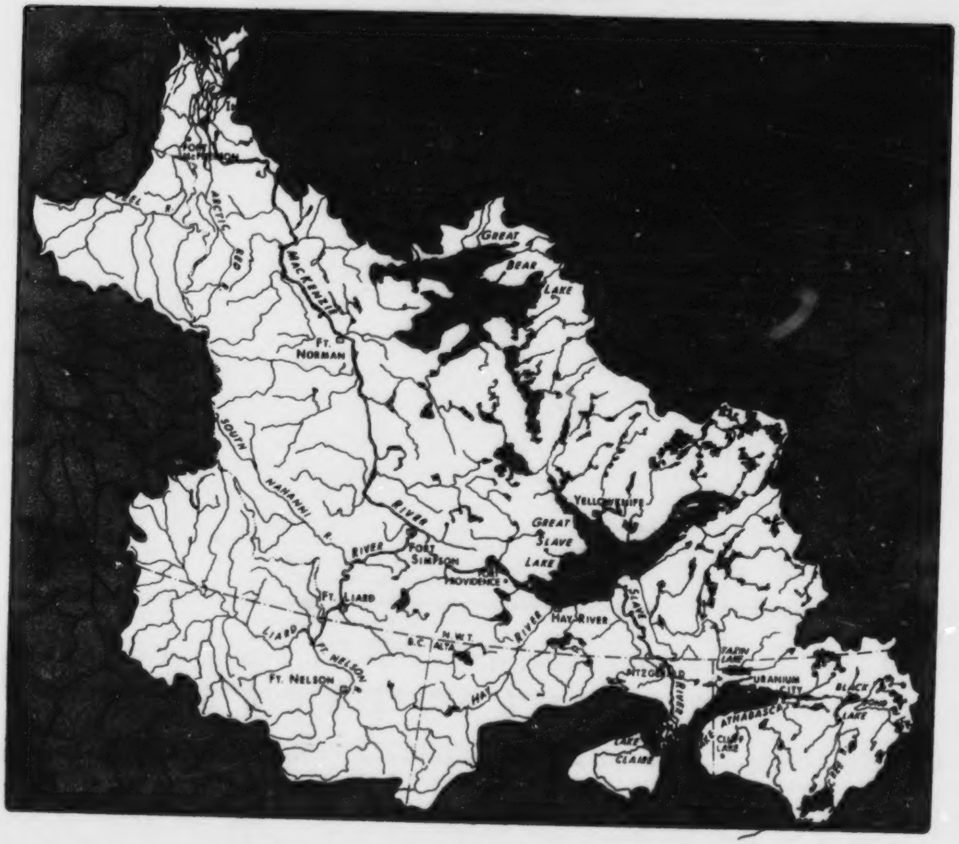
Figure 75. VARIATIONS IN LEVELS OF LAKE ATHABASCA BEFORE, DURING, AND FOLLOWING REGULATION AT WILLISTON LAKE; AND AFTER CONSTRUCTION OF A CONTROL WEIR AT THE NORTHERN OUTLET OF LAKE ATHABASCA (from De Boer, 1981).



in extensive damage downstream. Present and foreseeable use developments in the basin will not be limited by water supply or quality, except in small tributaries. Municipal supply and erosion and drainage problems exist and require the attention of water managers.

Instream uses in the main stem river are not substantial, although significant flow reduction due to any presently unforeseeable development could again inflict ecological damage at the Peace River delta. The SNBB (1972) identified two possible diversions of water from this basin to the Athabasca River, amounting to a total of over 550 m^3/s, which is about 25 percent of the mean annual flow of the Peace River. While no proposal has ever been made for this type of diversion, the lessons of the Peace-Athabasca delta would suggest the need for a careful evaluation of economic, social, and environmental effects if a proposal were ever made.

Figure 76. THE SLAVE RIVER/MACKENZIE RIVER BASIN.

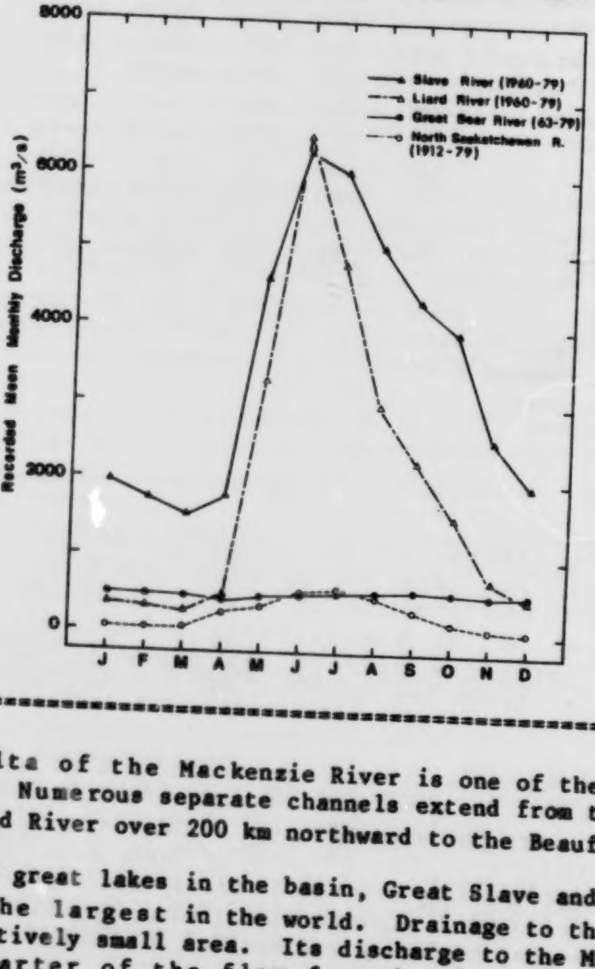

FORT McPHERSON
PEEL R.
ARCTIC RED
MACKENZIE
GREAT BEAR LAKE
FT. NORMAN
SOUTH NAHANNI R.
RIVER
YELLOWKNIFE
GREAT SLAVE LAKE
RIVER
FORT SIMPSON
FORT PROVIDENCE
FT. LIARD
HAY RIVER
LIARD
N.W.T.
B.C.
ALTA.
RIVER
FT. NELSON
FT. NELSON
HAY
SLAVE
TAZIN LAKE
FITZGERALD
URANIUM CITY
RIVER
BLACK
BOND LAKE
ATHABASCA
CLUFF LAKE
LAKE CLAIRE

4. SLAVE RIVER/MACKENZIE RIVER BASIN

The Slave River (Figure 76) connects the drainage from the Peace River and Lake Athabasca with Great Slave Lake, which forms the uppermost headwaters of the Mackenzie River. A major tributary of Great Slave Lake from the southwest is the Hay River. Downstream, the Liard River joins the Mackenzie from its over 220 000 km^2 drainage area. Other tributaries to the Mackenzie River drainage include the Arctic Red and Peel Rivers from the west, and the Great Bear River which connects Great Bear

Lake to the Mackenzie from the east. The relative dimensions of the flow of some of these rivers are illustrated in Figure 77, with inclusion of values for the North Saskatchewan River at Prince Albert for comparison. Hydrologic statistics for a few key locations in the basin are contained in Table 50.

Figure 77. COMPARISON OF FLOWS IN RIVERS OF THE SLAVE/MACKENZIE BASIN, AND THE NORTH SASKATCHEWAN RIVER.



The delta of the Mackenzie River is one of the largest in the world. Numerous separate channels extend from the mouth of the Arctic Red River over 200 km northward to the Beaufort Sea.

The two great lakes in the basin, Great Slave and Great Bear are among the largest in the world. Drainage to the latter is from a relatively small area. Its discharge to the Mackenzie is just one-quarter of the flow from the Liard River. The contribution from local drainage to Great Slave Lake Basin is larger but still much less than the drainage from the mountain and highland regions in the west.

TABLE 50. FLOW STATISTICS (m^3/s) FOR SELECTED POINTS - SLAVE RIVER/MACKENZIE RIVER BASIN (EC, 1980A; WER, 1980A)

RIVER	- HYDROMETRIC STATION (PERIOD OF RECORD)	MEAN ANNUAL	LOWEST ANNUAL	HIGHEST ANNUAL	LOWEST MONTHLY	HIGHEST MONTHLY	MIN. 5-YR. MEAN	MAX. 5-YR. MEAN
MACKENZIE	- FT. SIMPSON [2] (1965-79)	6760	5640 (1970)	8010 (1976)	1590 (MAR/69)	18 100 (JUNE/77)		
	ARCTIC RED RIVER [2] (1973-79)	9630	8100 (1978)	10700 (1974)	2720 (APR/79)	23 900 (JUNE/77)		
SLAVE	- FITZGERALD [2] (1921-79*)	3520	2590 (1970)	4340 (1974)	543 (MAR/53)	7930 (JULY/21)		
LIARD	- MOUTH [1] (1973-79)	2580	1770 (1978)	3070 (1976)	321 (MAR/74)	11 000 (JUNE/77)		
PEEL	- ABOVE FORT MCPHERSON [1] (1974-79)	776	620 (1978)	1040 (1975)	54 (MAR/78)	4470 (JUNE/75)		

1. RECORDED FLOWS - NATURAL
2. RECORDED FLOWS - REGULATED
3. COMPUTED FLOWS - NATURAL

* DISCONTINUOUS RECORD

Lake Athabasca, at the upper end of the Slave/Mackenzie River basin, has received considerable attention, primarily because of the effects on its western deltas from the construction of the W.A.C. Bennett Dam in British Columbia. Discussion of those effects are found in the last section. Recently, a report has described the recovery of the delta area (Smith, 1981).

Lake Athabasca also receives the drainage of rivers in Saskatchewan. The principal industrial development in that part of the basin are the uranium mines at Uranium City and Cluff Lake (Chapter VIII.4). The effects of these developments on water quantity and quality are not of widespread significance. There are indications of possible local water quality effects due to waste discharges, including radioactive substances.

North of Uranium City, water is diverted from Tazin Lake to a tributary of Lake Athabasca for the purpose of hydro power production to supply hydro power for the mine and municipality.

In addition to the hunting, fishing, and trapping uses in the western deltas, Lake Athabasca provides a commercial fishery. This fishery is presently small and variable. For example, the 1977-78 catch was about 350 000 kg which was reduced to 150 000 kg in 1978-79. One estimate of the potential of this industry is for an annual harvest of over 2 million kg per year. At present, walleye is the most important commercial species, although goldeye and whitefish are potentially important. A portion of the whitefish population is affected by a parasite problem. Concerns related to the fishery include control structures that block migration northward to the Slave River and possible ice-control structures near Fort McMurray which could affect southward migrations in the Athabasca River. The latter are under investigation, but are not yet proposed. There is also concern about possible water quality effects of developments in the Athabasca River basin (Chapter VI.2).

The Slave River is presently undeveloped, although flows from both the Peace River and Lake Athabasca are regulated. It forms part of the eastern boundary of Wood Buffalo National Park, which is inhabited by large herds of buffalo and contains the nesting grounds of the endangered whooping crane population. An island in the Slave River is populated by a colony of white pelicans, an unusual northern locale for this species.

The government of Alberta is presently evaluating the possibility of developing the hydro-electric potential of the river which could reach about 2000 MW. An interim report (R.L. Walker & Partners, Ltd., 1981) summarizes conditions in the project region and identifies some possible environmental consequences of a power dam. Further studies will provide more detailed information, but items presently identified include:

- inundation of stretches of the Slave River valley;
- loss of moose and bison range, bison migration routes, and waterfowl and muskrat habitat;
- sedimentation in the reservoir, which would reduce the load normally delivered to the Slave River delta;
- possible drowning of bison and other wildlife;
- possible increased mercury concentrations;
- possible loss of the white pelican colony;
- possible intrusion of the arctic lamprey upstream; and,
- depending upon dam characteristics, possible flooding of the Peace-Athabasca Delta.

Flooding of the Peace-Athabasca delta could significantly reduce wildlife productivity. The effects on fish would be mixed. Fish migration patterns would benefit, but thermal effects could be harmful. If Lake Athabasca were to be used as a storage reservoir for a Slave River project, there could be serious effects on fish and significant degradation of water quality.

In addition to environmental aspects, the construction of a dam on the Slave River could affect the livelihood of local persons depending on subsistence hunting, fishing, and trapping. It could also be quite beneficial in terms of local employment opportunities. Detrimental effects on downstream navigation were considered to be unlikely.

Provincial and federal water quality experts have questioned the observation made about mercury levels. In mid-1981, Alberta Environment was investigating the significance of recorded mercury level data. Alberta Environment is also continuing its investigations of this project with the intention of evaluating environmental effects and opportunities for compatability between the projects and the environment (Grover and Primus, 1981).

Water uses in the Northwest Territories portion of the basin are summarized in Chapter VIII. Offstream water uses are not expected to be limited by water supply in the drainage streams. Transportation of commercial goods on the Mackenzie River, however, can be constrained either by high flows which increase turbulent navigation conditions, or low flows which do not allow enough depth for safe movement. During 1980, low flow conditions in late August and September constrained both barge traffic and ferry crossing operations.

Of the major tributaries to the Mackenzie River, the Liard River is the most likely to experience future changes and regulation. B.C. Hydro is exploring possibilities for hydro development at several sites in British Columbia. Several potential concerns have been identified and are being evaluated by B.C. Hydro, including effects on transportation corridors in that region, effects on native lands and fisheries, damage to local ecology and environmental features, and downstream effects of flow regulation.

At present the Liard is unregulated. The proposed dam sites are close to native settlements and the Liard River Hot Springs Provincial Park. Several important fish populations use the river for spawning. The power utility does not plan to proceed with application for development until 1982, following additional studies.

TABLE 51. ESTIMATED FLOW CHANGES DUE TO HYDRO DEVELOPMENT ON THE UPPER LIARD RIVER (B.C. HYDRO)

LOCATION	PERCENT CHANGE SPRING	PERCENT CHANGE WINTER
LOWER LIARD	- 40	+ (100-200)
MACKENZIE R. NEAR FORT SIMPSON	- 20	+ 35
NEAR MACKENZIE R. DELTA	- 15	+ 30

The effects of flow regulation due to this project are illustrated in Table 51. The spring breakup of the Liard River, which occurs prior to breakup on the Mackenzie, results in earlier warming and ice removal in the Mackenzie River downstream of the Liard River inflow (Table 52). Regulation of the Liard could significantly alter that pattern. The possible effects of this on the climate of the Mackenzie Valley and the Mackenzie delta are unknown, but could be of concern.

The South Nahanni River, a tributary of the Liard, passes through Nahanni National Park. The spectacular beauty of the river and park have recently been documented in a National Geographic issue (September, 1981). Some mineral development occurs on tributaries to the river, upstream of the park, and Parks Canada is investigating possible water quality effects of those mines.

Mining operations are also located around Great Slave Lake and Great Bear Lake. Water consumption is not significant at these operations, but concern has been expressed in the past about water quality effects of operations near Yellowknife. Water-borne transportation related to mines has been important in the past, but in some cases is being replaced by other means of transportation.

TABLE 52. SELECTED BREAKUP DATES[1] ON THE LIARD AND MACKENZIE RIVERS

LOCATION	BREAK UP			YEARS OF RECORD
	EARLIEST	LATEST	MEAN	
LIARD RIVER AT FORT LIARD	1 MAY	31 MAY	11 MAY	16
LIARD RIVER NEAR THE MOUTH	9 MAY	12 MAY	10 MAY	3
MACKENZIE RIVER NEAR FORT PROVIDENCE	7 MAY	14 JUNE	23 MAY	11
MACKENZIE RIVER AT FORT SIMPSON	5 MAY	5 JUNE	18 MAY	12
MACKENZIE RIVER AT NORMAN WELLS	18 MAY	31 MAY	25 MAY	10

[1] DATES OF BEGINNING AND END OF ICE EFFECT (I.E., WHEN NORMAL STAGE-DISCHARGE CURVE CANNOT BE APPLIED DUE TO BACK-WATER EFFECTS FROM RIVER ICE).

SOURCE: WATER SURVEY OF CANADA DATA; SUMMARY COURTESY OF B.C. HYDRO

Chapter VIII.9 also describes the use of the main stem river as a transportation corridor. Although other modes of transportation will eventually become more significant, the use of the river is expected to continue to be important in the near future.

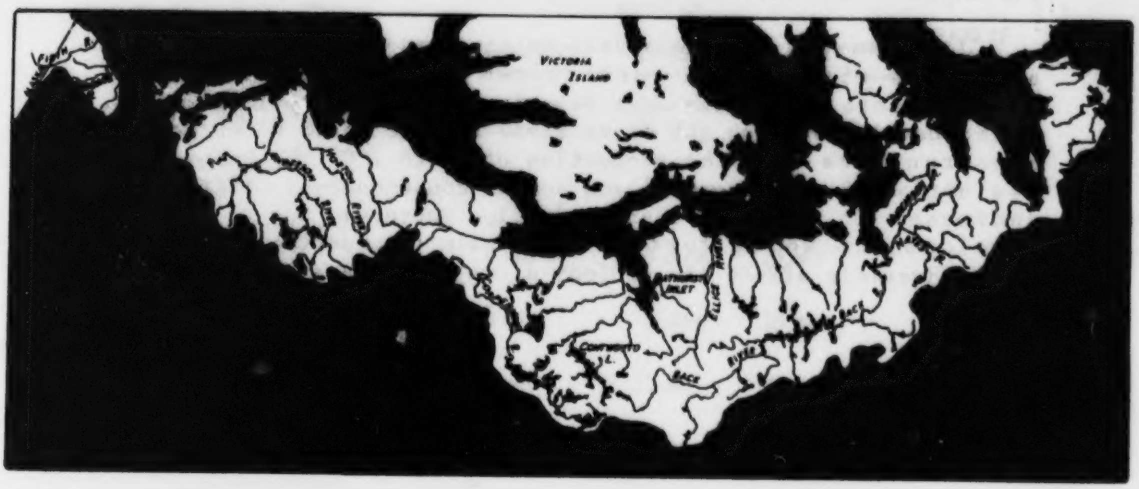
The Mackenzie River delta is an important wildlife and waterfowl region. At the northern end of the delta is located the Kendall Island Bird Sanctuary, and a large reindeer grazing reserve has been established just to the east of the delta and as far north as the coast of the Beaufort Sea. Immediately adjacent to the Mackenzie River delta, in the Beaufort Sea region, is potential oil and gas reserve area estimated to contain 95 billion barrels (16 billion m^3). The development of these reserves could eventually result in renewed interest in the use of the Mackenzie River valley as a transportation corridor, although the use of oil and liquefied natural gas tankers is being given active consideration as an alternative.

The effects of altered flow patterns of the Mackenzie River on the delta due to any combination of future events, including increased upstream regulation or diversions of water from the

system, are being studied. Of concern are the ecological effects in the delta region, and even possible effects on the climate of the adjacent Beaufort Sea.

In summary, offstream uses in the Slave/Mackenzie basin are small and will not be constrained by foreseeable future developments. Instream uses depend upon relatively large flows. Hydro developments on the Slave River and the Liard River present opportunities for the production of up to 7000 MW, but require evaluation of environmental and social consequences. Significant decreases in flow, or changes in flow patterns, due to upstream developments would further constrain transportation uses and could adversely affect the ecology of major delta areas.

Figure 78. OTHER DRAINAGE TO THE ARCTIC OCEAN.

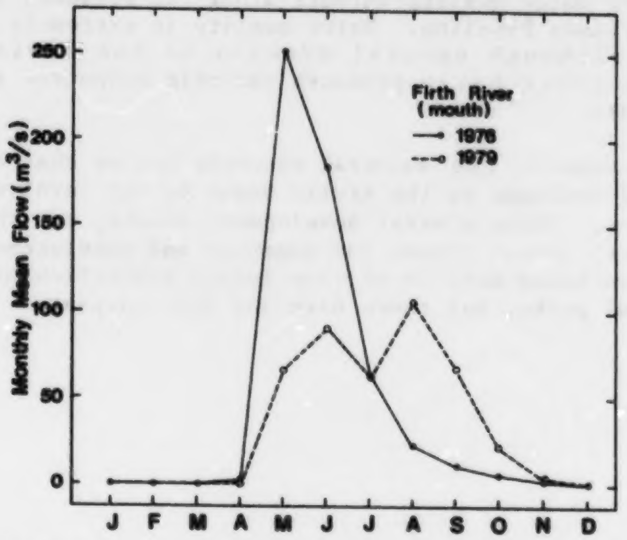


5. OTHER ARCTIC DRAINAGE

A number of rivers to the east and to the west of the Mackenzie River delta flow to the Arctic Ocean (Figure 78). Although the flows of major streams have been measured, and some studies have been performed relating to possible pipeline corridors, the surface hydrology of these rivers and their drainage basins is not well known. Consumptive water uses are almost non-existent and are unlikely to become significant.

On the northern edge of the Yukon Territory, several small rivers, including the Firth and Babbage, flow to the Beaufort Sea. The region is picturesque and an important habitat for a variety of wildlife, including the migratory Porcupine caribou and peregrine falcon. The federal government has proposed establishing this entire area as a national park, although an alternative would establish the area west of the Babbage River as a park, and the rest as a National Wildlife Area. A decision will likely await settlement of native land claims between the government and groups representing native interests. Some placer gold mining occurs along the Firth River.

Figure 79. EXAMPLES OF MONTHLY FLOWS OF THE FIRTH RIVER.



Discharge data for the Firth River are contained in Figure 79, for two recent years. Zero flow existed during January through March in both cases. The change from April to May in 1976 illustrates the dramatic and brief drainage of snowmelt in the spring.

To the east, a number of large basins exist, including the Anderson, Horton, Coppermine, Ellice, Back, and Hayes, as well as several smaller basins. The Back River is the largest, draining well over 100 000 km^2 with a mean annual discharge of over 600 m^3/s. The Anderson and Hayes discharge about 100 m^3/s each, and the Ellice about 75 m^3/s.

The region is prime nesting habitat for waterfowl, including the relatively scarce Ross's Goose. Native subsistence uses of waterways is scattered and not intensive. Recreational use is limited to small numbers of "fly-in" fishing parties.

Parks Canada has been evaluating an area near Bathurst Inlet as a candidate for a future national park. The possibility of mineral development in that area, with the use of the Inlet as a shipping harbour, is an alternative option for local inhabitants. Southeast of Bathurst Inlet, a gold mine at Contwoyto Lake is expected to begin operation in the near future.

Some areas in the eastern part of this region have been the subject of water quality surveys along the proposed route of the Arctic Islands Pipeline. Water quality is extremely good in all regions, although natural erosion in the lowlands of the Murchison River basin produces variable suspended and disolved solids values.

In summary, the several discrete basins that comprise the balance of drainage to the Arctic Ocean do not involve many water use issues. Some mineral development exists, but the major use is by local inhabitants for domestic and subsistence purposes. Efforts are being made to provide future protection of some lands for national parks, but these have not been completed.

PART D.
WATER USES

CHAPTER VII

WATER USE CHARACTERISTICS

1. WATER USE CHARACTERISTICS

Water resource managers throughout the Study Region have adopted similar classifications of water uses. Furthermore, water managers have found it convenient to use the classification system itself as a tool of management (e.g., in the ranking of allocation priorities). For the purposes of this study it was decided to use a fairly broad classification system: irrigation, other agricultural, industrial, municipal, electric power production, recreation, renewable resource utilization, and transportation.

Irrigation

Irrigation is the largest consumptive user of water within the Study Region, although it is barely significant or even non-existent in the more northerly drainage basins. Crop production in the southern agricultural lands is sensitive to two types of water deficiency: lack of direct precipitation for soil moisture and ground-water maintenance and lack of streamflow supplies for irrigation. These deficiencies do not always occur simultaneously, but when they do, the worst drought conditions can result (Chapter II.3). In locations where direct precipitation is frequently inadequate for agricultural uses, district or private irrigation projects have become established. Detailed descriptions are found in Chapter VIII.2.

TABLE 53. MONTHLY DISTRIBUTION OF WATER WITHDRAWAL
ALBERTA IRRIGATION DISTRICTS (MER, 1980a)

	PERCENT OF ANNUAL USE					
	APRIL-MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
ST. MARY PROJECT [1]	9	17	30	22	14	8
LETHBRIDGE NORTHERN [1]	10	23	28	18	12	9
UNITED [2]	11	22	20	17	16	14
MOUNTAIN VIEW LEAVITT-AETNA [2]	7	15	20	27	18	13
WESTERN [2]	16	20	24	22	17	1
BOW RIVER [2]	7	19	37	18	10	9
EASTERN [2]	10	16	29	21	15	9

1. AVERAGE FOR PERIOD 1967-75
2. AVERAGE FOR PERIOD 1974-78

While many uses of water are relatively constant throughout the year, irrigation is seasonal (April through October) and varies from year to year according to climatic conditions. The monthly distribution of water use in the Alberta irrigation districts averaged over several years is illustrated in Table 53. Because needs are seasonal and do not usually coincide with periods when stream supply is greatest, efficiencies are sought through the construction of storage works, either on the streams or adjacent to them. During high flow periods, water can be stored for use during periods of low flow.

For major irrigation projects, works are also needed to transport water to the irrigator and to return excess water from the associated drainage systems. Both the storage and the conveyance systems result in losses of water from local productive use because of evaporation and leakage.

Three types of irrigation are employed in central North America: water spreading by back flooding, where water is applied with spreader dykes during peak flood season; sprinkler irrigation; and irrigation by gravity border dyke or border ditch, where water is pumped or gravity-fed in a systematic way during the irrigation season.

Traditionally, most private projects were irrigated either by spring flooding or by a surface ditch or dyke system, using water diverted directly from streams. Partly because of the labor-intensive aspects of these methods, there has been a recent switch to sprinklers, particularly large centre-pivot systems. Sprinkler systems do not require land levelling and therefore enable the irrigation of more irregular terrain. The result of this change is a shift in the demand schedule from mainly spring use to a summer-long demand. Sprinkler systems make more efficient use of available water, but require storage works, especially if the projects are supplied from intermittent streams. Storage works are not required when ground waters are used. Thus, a much different pattern of use is emerging compared to former procedures.

Crops under irrigation, whether grains, forage, or other, have roughly defined water quantity requirements. For major irrigation districts in dry regions (e.g., southern Alberta), water diversions of between 0.6 and 1.9 dam^3 are required per acre irrigated (1.6 - 4.7 dam^3 per ha) in a dry year (Environment Canada, 1978a, 1979a, 1980c). For a description of water quantity requirements of specific crops, the reader is referred to Canada, Department of Agriculture (1943).

Agricultural practices have an influence on the conservation and efficient usage of water, which in turn influences irrigation requirements. This is a complex subject not treated in this report. The federal Agriculture Research Centre at Swift Current, Saskatchewan, has produced several reports on this subject.

During irrigation, water is applied to the land to supplement naturally available water, and thereby provide sufficient water for plant growth. Plants use part of the irrigation water in transpiration. The remainder may evaporate from the soil, percolate to ground water, or drain off as return flow. The major effect of irrigation on water quantity is the very substantial local loss of water due to evaporation and transpiration. While this is difficult to measure, estimates of total losses (including those due to leakage, etc.) have been made in some locations. Environment Canada (1979a), for example, estimates return flows in southern Alberta annually, and finds an average consumption of about 75 percent in dry years (see also WER, 1980). This does not include evaporation losses from major onstream reservoirs.

When water is transpired by plants or evaporated from the soil, the materials that were dissolved in the water are left behind. As these materials accumulate they may reach concentrations that impair growth or are toxic.

Accumulation of salts from irrigation water may be restricted to below the zone of root development through careful application of just sufficient water to ensure leaching of the concentrated materials. This is done by applying water in excess of what is required by the plants, so that the materials removed by percolation are equal to the materials added from the irrigation water. However, application of excess irrigation water may result in several other problems.

If ground-water drainage is poor the water table can rise, causing water-logging and increased salinization of the soil, if the ground water is saline. If evaporation and transpiration are large, the concentration of dissolved solids in return flow can impair the water quality of receiving waters. It is possible that irrigation use in one district could eventually degrade water sufficiently to constrain downstream irrigation or other uses.

Water quality standards for irrigation of alkaline and acidic soils are described in a report by FitzGibbon (1981), although different crops may have substantially different requirements. Even when water quality standards are met, alkaline soils should not be irrigated for a period of more than 20 years, because most alkaline soils occur in areas where water losses to evaporation and transpiration are large, creating a rapid accumulation of dissolved salts (i.e. salinization in the soil).

For acidic soils, the allowable concentrations of metallic ions are much less than those required for alkaline soils, due to the higher mobility of many of these ions under acid conditions. These standards do not place a long- term restriction on irrigation as in the case of alkaline soils.

Water quality requirements also depend upon the crop under irrigation. Some crops are sensitive to moderately high levels of total dissolved solids (TDS), while others are very sensitive to other chemical constituents, such as boron. As a recent example of an evaluation of this concern in waters of this Study Region, the reader is referred to the International Joint Commission (1979) study of the Poplar River in Saskatchewan and Montana.

Other Agricultural Uses

Other agricultural uses include stock watering and farm domestic use. Water supplies include streams, lakes, wells, dugouts, and irrigation canals. Quantities required for stock watering depend upon herd sizes and types of animals. These amounts vary and are described in more detail in Chapter VIII.3.

The water quality required for stock watering (FitzGibbon, 1981) indicates the levels beyond which serious problems can occur (i.e., mortality or greatly reduced growth). The impact of water quality varies with the type of livestock. Poultry and hogs are more sensitive to water quality than cattle or sheep. Dairy cattle require higher quality water than beef cattle, as poor water quality will reduce production and impart an undesirable taste to milk.

A problem in some areas is that of selenium deficiencies. It has been suggested (Alberta Agriculture, 1973, and Sondha et al, 1980) that sulphur can block or reduce the amount of selenium taken in by plants and animals, causing white muscle disease (nutritional muscular dystrophy) in animals. As the concentration of sulphates in the environment (produced from combustion of sulphide-containing fuels and processing of gas and oil) increases, this problem could become more significant.

TABLE 54. RECOMMENDED LIMITS FOR DRINKING WATER QUALITY IN CANADA

(HEALTH AND WELFARE CANADA, 1979)

PARAMETER	MAXIMUM ACCEPTABLE CONCENTRATION*	OBJECTIVE CONCENTRATION**
ALDRIN + DIELDRIN	0.0007	LE 5×10^{-8}
ANTIMONY	—	LE 0.0002
ARSENIC	0.05	LE 0.005
ASBESTOS	—	—
BARIUM	1.0	LE 0.1
BORON	5.0	LE 0.01
CADMIUM	0.005	LE 0.001
CARBARYL	0.07	LE 5×10^{-4}
CHLORDANE (TOTAL)	0.007	LE 5×10^{-8}
CHLORIDE	250	L 250
CHROMIUM	0.05	LE 0.0002
COLOUR (TCU)	15	L 15
COPPER	1.0	1.0
CYANIDE	0.2	LE 0.002
DDT (TOTAL)	0.03	LE 5×10^{-8}
DIAZINON	0.014	LE 1×10^{-6}
DIELDRIN + ALDRIN	0.0007	LE 5×10^{-8}
ENDRIN	0.0002	LE 5×10^{-8}
FLUORIDE	1.5	1.0***
HARDNESS	—	—
HEPTACHLOR + HEPTACHLOR EPOXIDE	0.003	LE 5×10^{-8}
IRON	0.3	L 0.05
LEAD	0.05	LE 0.001
LINDANE	0.004	LE 1×10^{-7}
MANGANESE	0.05	L 0.01
MERCURY	0.001	LE 0.0002
METHOXYCHLOR	0.1	LE 5×10^{-8}
METHYL PARATHION	0.007	LE 1×10^{-6}
NITRATE (AS N)	10.0	LE 0.001
NITRILOTRIATIC ACID (NTA)	0.05	LE 0.0002
NITRITE (AS N)	1.0	LE 0.001
ODOUR	—	INOFFENSIVE
PARATHION	0.035	LE 1×10^{-6}
PESTICIDES (TOTAL)	0.1	—
PH	6.5 - 8.5	—
PHENOLS	0.002	L 0.002
SELENIUM	0.01	LE 0.002
SILVER	0.05	LE 0.005
SODIUM	—	—
SULPHATE	500	L 150
SULPHIDE (AS H_2S)	0.05	L 0.05
TASTE	—	INOFFENSIVE
TEMPERATURE (°C)	15	L 15
TOTAL DISSOLVED SOLIDS	500	—
TOTAL ORGANIC CARBON	—	—
TOXAPHENE	0.005	LE 5×10^{-8}
TRIHALOMETHANES	0.35	LE 0.0005
TURBIDITY (NTU)	5	L 1
URANIUM	0.02	LE 0.001
ZINC	5.0	L 5.0
2, 4-D	0.1	LE 0.001
2, 4, 5-TP	0.01	LE 0.001

UNLESS INDICATED OTHERWISE, THE MAXIMUM ACCEPTABLE AND OBJECTIVE CONCENTRATIONS ARE SPECIFIED IN MG/L

* MAXIMUM ACCEPTABLE:
DRINKING WATER THAT CONTAINS SUBSTANCES IN CONCENTRATIONS GREATER THAN THESE LIMITS IS EITHER CAPABLE OF PRODUCING DELETERIOUS HEALTH EFFECTS OR IS AESTHETICALLY OBJECTIONABLE.

** OBJECTIVE:
THIS LEVEL IS INTERPRETED AS THE ULTIMATE QUALITY GOAL FOR BOTH HEALTH AND AESTHETIC PURPOSES.

*** IN AREAS WHERE THE ANNUAL MEAN MAXIMUM TEMPERATURE IS BELOW 10°C, THE OBJECTIVE IS 1.2 MG/L.

L = LESS THAN

LE = LESS THAN OR EQUAL TO

Under conditions where surface waters receive large nutrient loads (e.g., runoff contaminated by fertilizer or animal wastes) algal blooms can occur. Certain types of algae are poisonous and the decay of algae reduces oxygen levels in the water. The resulting anaerobic conditions produce objectionable water odours and tastes for animals. The use of pesticides is common in areas where spills could contaminate stock water, resulting in loss of livestock (FitzGibbon, 1981).

Recommended limits for drinking water quality are contained in Table 54. Water of poorer quality can be used for other household and farmstead uses. In some rural areas of western Canada these guidelines are not met. The major problems are high levels of dissolved solids, salts, iron and nitrates. Problems of algal contamination are of particular concern where dugouts or other local water bodies are used for household water. In many areas drinking water is not drawn from wells or dugouts, but is derived from cisterns or hauled from community wells.

Industrial

Industrial use includes only those industrial uses which do not draw upon municipal water supplies, although available data do not always make this distinction. As a result, there is some uncertainty involved in the use of industrial data. Statistics Canada is a principal source, inasmuch as it surveys water use by Canadian industries. The level of detail used in this survey includes six separate industrial categories: mines and quarries; food and beverage; petroleum, coal, and chemical products; forest products; non-metallic mineral products; and miscellaneous. Under the federal Statistics Act, the government is not allowed to release specific details of water-use characteristics for each individual industrial water user, although it is permitted to release summaries of information by user type. Because not all individual users respond to these surveys, it is sometimes necessary to calculate rates of water withdrawal and consumption for a particular user group, and then to apply those rates to the complete body of users within that group.

Statistics are also available from other federal agencies and provincial agencies that license individual water users. In this case, however, it is not always certain whether the licensed amount of water is actually withdrawn. Furthermore, there is little information available from licensing agencies concerning the volumes of water consumed by specific users. Nevertheless, because industries are not major consumptive users of water in the Study Region, the use of statistical procedures and generalized assumptions does not pose a serious problem to the analyses contained within this study.

The self-supplied industries are, for the most part, the resource industries such as mining, petroleum, chemical, and forest products. Manufacturers and other small industries normally use smaller volumes of water and are usually supplied from municipal systems, the food and beverage industry often being an exception.

There is a great variety in the way water is used by industries. The wood industries do not individually use much water, but pulp mills withdraw as much as one m^3/s, equivalent to 30 000 dam^3 annually. Water is used for digesting wood chips, pulp washing, boiler feed, and cooling. The quality of water input has a direct impact on processing techniques, end-product quality, and equipment lifetime. The rate of water recirculation is relatively high (new water being recirculated about three times) and water consumption is low. Discharges from processing facilities often place large biological oxygen demand and suspended solids loadings in receiving waters.

Water is involved in nearly all aspects of mineral development, but the greatest concerns arise at the mining and milling stages. Some mines require constant pumping to prevent inundation from ground-water seepage. In milling, large quantities of water may be required for washing or as a medium in which other processes occur. Recycling is commonly practised, with water pumped from mines sometimes used in the mill; but total effluent volumes are nonetheless large. In smelting and refining, water is used for cooling, processing, boiler feed, and other purposes. Waste waters are discharged to nearby lakes or streams or, more commonly, to tailing ponds. Since the effluent can contain traces of heavy metals and radioactive elements, care must be exercised in locating, designing, and constructing the disposal pond, including lining it if necessary. Otherwise decanted water (from discharge ponds) and seepage into ground water could eventually pollute surface or ground waters.

Uranium developments, like other mining operations, require water for processing and also must deal with ground water flooding in excavations. Process water effluent is usually discharged to settling ponds before being returned to the drainage system. There is apparently very little net consumption, but this aspect is not yet well known for the uranium mining industry.

Depending upon the quality of the ground water pumped from the mines, it may be (i) used for processing, (ii) treated before discharge to surface drainage, or (iii) discharged directly to surface drainage. For this reason, actual water uses vary from mine to mine.

The potash industry presently withdraws water from both surface and ground water sources. Requirements are about one m^3 per tonne of product. The water, once used, is too saline for return to the source and is disposed either in surface evaporation ponds or in deep wells. Solution mining, a technique exclusive to Saskatchewan, is used at a mine just west of Regina. The process involves pumping hot water into potash layers 1600 meters below the surface where it dissolves potassium and other salts. The saturated salt solution is pumped to the surface and the potassium salt is extracted from the solution through evaporation and crystallization.

Extraction of conventional oil involves drilling wells and pumping oil to the surface. The producing formation is frequently 'stimulated' through the injection of acids or sand/water mixtures, under pressure, into the formation. Oil recovery has been even further enhanced through the injection of water (water-flooding), carbon dioxide, natural gas, and other materials to force the oil to the producing well.

Approximately 80 percent of the water used for oil field injection in Alberta is surface water, whereas all licenses in Saskatchewan are for ground water (MacLaren, 1980). The water ultimately remains in the oil formations. As oil supplies dwindle, use of water for this enhanced recovery will probably increase. The water required for this process does not need to be of high quality, and it is possible that low quality effluent from other uses could be employed.

Future developments in the mining industry could have a considerable impact on water resources. Mining of oil sands in the Athabasca River basin presently accounts for the use of large quantities of water, and a number of new plants are expected to be onstream within the next 15 to 25 years there and elsewhere (such as in the Peace River basin). An interesting review of economic and technical aspects of oil sands and heavy oil developments has been published by the Environment Council of Alberta (1978a).

A typical oil sands plant presently requires water withdrawal of about two cubic metres per barrel of oil (0.16 m^3 of oil) produced, until a steady recirculating procedure is reached when this can be reduced significantly. The next generation of oil sands plants are expected to use only about 0.5 m^3 of water per barrel of oil after water recycle is established. Although procedures will likely vary from plant to plant, it can be assumed that only a small fraction of fresh water used will be returned to the surface drainage.

Two large mining operations presently strip and process the Athabasca Oil Sands. A hot water, chemical, and steam process is used to separate the bitumen from the sand. Clay and water are then removed, after which the bitumen is up-graded and transported to Edmonton as synthetic crude oil. Tailing ponds receive the slurry (sand, clay, water and unrecovered bitumen) that remains after the bitumen has been extracted, fluid wastes generated by all plant processes, plus any saline ground water that may be pumped from mine excavations.

In the Lloydminster area, where the oil is thick (heavy oil) and in sandstone formations, steam injections and fire-flooding (burning a small portion of the oil 'in situ') have been tested. Similarly, at various locations in the Cold Lake Oil Sands deposit, consideration is being given to steam extraction of oil from layers of sand 30 metres or more in thickness, at depths between 270 and 500 metres. Fresh-water requirements for extraction and upgrading will be approximately 0.65 m^3 per barrel of oil produced for the 22 000 m^3 per day (140,000 B/D plant). Water quality concerns for in situ projects primarily relate to ground water. For mining type operations, they can relate to both surface and ground water.

Water requirements for petroleum refining, gas processing and a variety of petrochemical industries vary and are sometimes provided from municipal supplies. An example of water use in the petrochemical industry is a projected 0.6 m^3/s flow of process water for six plants foreseen near Red Deer, Alberta (ECA, 1977).

Water use in the processing of coal is significant. Coal for prairie power plants is used directly after crushing and pulverizing, with no washing; but large volumes of water are drawn from mountain streams and rivers to clean bituminous coal before it is shipped by rail to markets. Though water recycling may increase, discharge of waste water to settling ponds and subsequent water infiltration can present water quality problems. Runoff water from mining operations is usually controlled, but dissolved solids and seepage to ground water are more difficult to monitor.

Hydraulic mining of steeply pitched seams of mountain coal is being employed in southeastern British Columbia, and could soon be used in Alberta. Slurry pipelines using oil or water are a possible future mode of coal transport, possibly involving large volumes of water or other fluids. Within the next 20 to 30 years, coal conversion to liquid fuel oils or gas may be practised on a large scale. Large amounts of water as steam would be used as a source of hydrogen to perform the conversion.

Municipal

The municipal category includes all demands placed upon water supply to municipalities, including both domestic and local industrial needs. Within the Study Region there are five large cities: Edmonton, Calgary, Saskatoon, Regina, and Winnipeg. There are also several cities whose populations number in the tens of thousands and hundreds of smaller urban areas.

Some major municipal centres withdraw their water directly from adjacent streams and return their effluents to the sources. Others (Regina and Winnipeg) use wells and distant lakes as sources, but discharge effluents to local streams. Although information exists pertaining to the volumes of water withdrawn from rivers for the major urban areas, it is very difficult to specify with accuracy the uses to which the water is put, particularly for a city like Calgary, which does not completely meter all domestic uses. Consequently, information is not always accurate concerning the amounts of water used by different user groups. For the Study Region as a whole, the breakdown of average flows to each user category is estimated as follows (Environment Canada, 1978c):

residential - 41 percent
commercial/institutional - 30 percent
industrial - 20 percent
system losses - 5 percent, and
unaccounted - 4 percent.

Information available on actual volumes of water withdrawn from wells is sparse.

Data on municipal uses are usually available from specific municipalities or regional planning agencies. Environment Canada attempts to summarize this information in a data system called MUNDAT. On a per capita basis, potable water uses amount to approximately 673 litres per day (Tate & Lacelle, 1978). The range in daily per capita withdrawals in the Study Region is between 890 litres for the Territories and 415 litres for Saskatchewan, though this figure is probably lower in some small communities. The north has a high daily per capita value which is attributed to the fact that water is allowed to flow continuously during the winter periods to prevent freezing.

There is some net consumptive loss due to municipal water use. The calculation of this loss, however, is complicated when both surface and ground water supplies are used, and when there is mixing of local storm drain runoff with treated waste-water flows. Because most precipitation falling on an urban area is captured by storm drainage systems, the total return flow to a river may be equal to, or exceed, amounts withdrawn for municipal use, thus masking internal consumptions (MacKenzie, 1981). In any case, there is an average net consumption by major municipalities of about 18 percent (Tate, 1980).

Specific water quality requirements for domestic use are contained in Table 54. In some cases there may be additional specific requirements imposed because of particular industrial needs.

Water withdrawn by municipalities usually requires some treatment prior to use. This can include, according to local requirements: aeration, carbon absorption, chlorination, coagulation, filtration, fluoridation, iron and manganese removal, ozone disinfection, pH adjustment, softening, sedimentation, and taste and odour control.

Waste effluent from municipalities is usually treated before it is returned to rivers. Although some basic treatment processes for municipal waste are relatively inexpensive and routine, those processes which ensure a significant reduction in nutrients can be very costly. The types of treatment most commonly available are: disinfection, a variety of primary treatments (e.g., clarification, screening), stabilization, ponding, biological treatment, tertiary treatment (e.g., phosphorous removal), and sludge processing.

Ordinary domestic use of water can cause quality impairment depending upon the level of subsequent waste-water treatment. Domestic wastes contain micro-organisms hazardous to health and nutrients which, if present in sufficient quantities, can result in undesirable biological growth in the receiving waters (Chapter II.4). The domestic use of various pesticides for weed and insect control is also a potential source of water pollution due to runoff from urban areas. In addition, there are a variety of significant adverse water quality effects which can stem from the industrial uses of water within municipalities. These are described in discussions of specific cases.

Electric Power Production

Two quite different methods of electric power generation that require water are employed in the Study Region. Thermal power generation involves the use of coal, natural gas, or oil, to produce steam to drive a turbine generator. Nuclear power generation exists in parts of Canada, but not yet in the Study Region. Hydro power generation involves the harnessing of the force of flowing water to drive turbines.

Water is used in two major ways in a thermal power plant. In a closed cycle, it is converted to steam in a boiler and expands through the turbine driving an electric generator. This steam then passes through a condenser where water in a second, separate system removes heat from the steam to convert it back to water before being passed through the boiler again. The use of water for cooling is much greater than for the production of steam. The demand for cooling water is directly proportional to the electric power produced, and proximity to a water supply is a major consideration when locating a thermal power plant.

A few of the small early power plants in the Study Region use a "once-through" cooling system, where the required water is extracted from a river upstream of the power plant, passed through the condenser, and discharged into the river downstream of the plant. This type of system requires large volumes of water (typically 40 m^3/s per 1000 MW of installed power capacity) and is not practical for large power plants. Consumptive water use due to increased evaporation in the river in this case is relatively small.

On rivers where the flow variation is such that insufficient quantities of water are available at certain times of the year to allow once-through cooling, a storage reservoir can be established on the river. The river must have sufficient flow such that the evaporation from the surface of the reservoir does not exceed the inflow to the reservoir plus the downstream riparian rights, and the water temperature at the outfall structure is maintained at or below government-set limits. With this type of system, it is necessary that the intake and outfall structures are sufficiently separated to allow enough time for the water to cool prior to being recycled. In the spring and early summer, except for very dry years, river flows are usually sufficient to flush the reservoir and eliminate the build-up of dissolved solids due to evaporation.

Another cooling arrangement involves locating the thermal power plant adjacent to a natural lake. The lake must have sufficient inflow of water to compensate for the forced evaporation resulting from the addition of warm water from the plant. Alternatively, a cooling pond can be established near a plant and water pumped from a nearby or distant river. In this case, make-up water pumping may be done over the entire year or for a portion of the year. The water to be supplied must not only be sufficient to replace water lost to natural and forced evaporation, but also to replace water used to flush out the artificial impoundment. For a typical 750 MW coal-fired station of this type, the make-up required from the river is about 0.6 m^3/s about one-half of which is consumed by evaporation (Frey, 1980). It is of interest to note that the ratio of cooling water flow through the condenser to the make-up flow from the river is about 38 to 1.

Water losses due only to forced evaporation from natural or artificial impoundments vary considerably with climatic conditions. Under Canadian prairie conditions, a realistic estimate would be about 0.2 m^3/s per 1000 MW of installed capacity, based on average conditions (UNIES, 1980). For example, about eight percent of the maximum volume of Boundary Reservoir near Estevan, Saskatchewan is lost each year to forced evaporation caused by the operation of the Boundary Dam Generating Station (Kenney, 1978).

Other water losses include natural evaporation and seepage. Natural evaporation on the prairies varies between 40 and 95 cm per year (Gray, 1970), and annual precipitation varies from 30 to 60 cm per year. Net evaporation on lakes and reservoirs varies from less than 7.5 cm north of the 55th parallel, to a maximum of 65 cm in a dry area north of a line between Medicine Hat and Swift Current. Seepage loss estimates are difficult to make without field testing. Estimates of total consumption due to forced and natural evaporation and seepage vary from 0.2 to 0.4 m^3/s per 1000 MW for an "average" station (UNIES, 1980).

In addition to cooling, water is used to limit the build-up of dissolved chemicals in the boiler water, to dispose of solid waste, and to reduce atmospheric emissions. Water discharged from these functions may carry quantities of dissolved and suspended materials which may be reduced by settlement and water treatment. However, the level of treatment varies widely from one installation to another. The quality of released water is greatly influenced by: the quality of fuel burned, atmospheric emission and receiving water standards, the size of the receiving water stream, competing water uses, and the pattern of release to receiving water.

Hydro-electric plants do not require external fuel supplies, as they depend upon gravity-driven water power for their turbines. Although the hydraulic "head" at any location can be increased by the artificial raising of the water elevation with a dam, the natural hydraulic gradient is critical. By application of sound planning principles, the maximum potential of each river or river segment can be determined.

Storage reservoirs for hydro-electric power generation in the prairie provinces are of two types. One is the small volume reservoir used each day for a short period of time to meet peak demands. The average power generated by this type of plant is 20 to 30 percent of peak generation and the operation produces a corresponding daily fluctuation in local streamflow. The second type of reservoir is much larger relative to streamflow and is used for augmentation during extended low streamflow periods. In this way, the reliable energy production of generating plants downstream of the reservoir is increased, and the flow pattern in the entire river downstream is usually altered. The regulated pattern of flows can be changed as the electrical load and the mix of generation facilities meeting that load change.

Water consumption by hydro stations is due primarily to increased evaporation from new reservoirs, which present larger surface areas than do the natural streams. Estimates of evaporation can be determined by methods described earlier for thermal plant reservoirs.

Effects of dams and reservoirs on water systems can be positive and negative. Inundation of lands adjacent to the stream can alter erosion and sedimentation patterns, increase or reduce fish and wildlife populations and habitat, change fish migration patterns, and cause local problems due to the elevation of the ground water regime. Other downstream effects are usually dependent upon the operational procedures associated with power generation. Rapid changes and great reductions in flow are harmful to fish and fish habitat. Increased flows can lead to more favorable oxygen concentrations, especially during winter months when fish kills might otherwise occur and sewage might not be degraded. Some recreation, such as canoeing, is also affected by changes in the natural flow pattern.

New reservoirs can increase certain types of recreation, make new types of recreation possible, increase shoreline waterfowl habitat, and be developed for commercial fisheries. Operational procedures also can be beneficial downstream, if water supplies are augmented during normally low-water periods. This can benefit a variety of instream and offstream uses by assuring firm supplies and maintaining minimum flows for fish or effluent dilution.

Recreation

Recreational uses of water are both tangible and intangible, and it is often very difficult to evaluate recreation in comparison with competing water uses. Nevertheless, as populations acquire more leisure time, the recreational use of water will become increasingly significant.

Water quantity requirements for recreation are not easily defined. In some cases the requirement may simply be the natural flow or the availability of water in natural lakes and wetlands. In other cases recreational demands may help to justify artificial measures that will ensure adequate supplies for boating, fishing, and swimming. Although water storage and diversion, and the artificial management of flows resulting therefrom, may have adverse effects on recreation, there are instances where they have positive effects such as the provision of necessary minimum flows during periods of naturally low supply. Except where water is stored or released from storage primarily for its purposes, recreation has no effect upon water quantity.

Water quality requirements for recreation can be among the most stringent for all uses. Waters must meet certain health-related standards in areas used for swimming and other water-contact sports. Also, even though they may not relate directly to health aspects, the problems associated with eutrophication (Chapter II.4) constitute one of the most common recreation-related water quality concerns in the Study Region. In some cases the growth of algae and weeds is related to the natural occurrence of nutrient-rich waters, though there are instances where this is aggravated by agricultural or municipal effluents.

The water quality of fish habitat can be severely affected by other water uses. The presence of pesticides, mercury, and polychlorinated biphenols in the water environment can be a serious problem either for fish or persons eating fish. In some cases, toxic materials such as mercury and arsenic are present naturally, but their effects can be amplified by activities such as dredging of contaminated sediments.

Activities that can affect the natural processes of erosion and sedimentation can also seriously affect fish populations. Natural spawning areas in rivers and lakes can be damaged by the deposition of erosion products from upstream activities. Additional spawning areas can be produced as a result of new reservoirs.

The destruction of natural wetland areas, through drainage and tillage, can be a significant encroachment on habitat required for many species of birds and wildlife important to certain aspects of recreation.

Indeed, it seems as though recreation is the use that is most frequently in conflict with other uses of water. Partly in recognition of this, and partly in recognition of man's responsibility as a steward of the environment, certain areas have been set aside as parks, wildlife refuges, heritage rivers, and the like (Chapter I.6). Varying degrees of protection of water resources are imposed in these areas, sometimes in part for reasons of providing recreational opportunities.

Recreational activities can significantly affect water quality. Wastes disposed to water bodies from adjacent cottage developments, for example, can significantly affect their quality.

Renewable Resource Utilization

Renewable resource utilization is the category intended to include the variety of requirements for water by those uses which exploit renewable resources, such as fish, wildlife, and forests. Some examples are commercial and subsistence hunting, fishing and trapping; and the primary aspects of the forestry industry.

The water requirements for hunting, fishing and trapping are essentially the same as for the recreational usage of fish and wildlife resources. The effects of these activities on the water resource are not significant except in cases where control structures are established primarily for their benefit.

The growth and harvesting of commercial forests have no requirement for waters in surface drainage systems, except where streams and lakes are used for conveyance of logs. This practice can result in the presence of waste materials (logs, chips, bark) in the waters and along the banks of streams. In severe cases, accumulations of materials on river and lake bottoms can result in oxygen reduction.

The threat of fire in forested areas is increased when soil moisture is reduced. Any large scale alteration in the hydrologic system which would alter soil moisture conditions could, therefore, be influential in this regard.

Forestry practices have been shown to affect local hydrology (e.g., Swanson and Hillman, 1977). Clear-cutting can significantly increase streamflow during snowmelt periods (by 59 percent in one test case in western Alberta), increase net yield, and increase storm runoff peaks. Forest harvesting can also increase erosion products in streams, although the coincidence of this with peak diluting flows reduces local water quality impairment.

Clearing of forested land for transportation and oil and gas exploration purposes can significantly increase soil erosion with consequent effects on the quality of waters of nearby streams. "During 1971 in Alberta, more forest was cut by the petroleum industry than by the forest industries for lumbering, pulp and paper, and fuel" (Environment Canada, 1979b).

Transportation

The transportation category is confined to situations where water bodies are used for purposes of transportation. It does not include effects or requirements of land-borne transportation upon water resources.

The use of waterways for transportation in the southern portions of the Study Region is mainly restricted to a few ferry locations and some recreation and commercial travel on large lakes. Of more significance is the use of the Athabasca/-Mackenzie waterways to move large volumes of dry goods and petroleum products economically to many remote communities.

Transportation requires certain minimum depths for the passage of vessels. The effects of hydro developments and interbasin transfers could be of concern because of their potential effects on water levels. For example, hydro developments on the Slave, Peace, and Liard Rivers have been identified as a possible major concern to downstream navigation, although detailed studies predicting water-level effects of specific dam sites have not been completed (Dickins, 1980).

Transportation has no effect upon water quantity except where regulation occurs for the convenience of transportation. Effects on water quality due to normal vessel discharges are small compared to those produced by community discharges. A more serious matter is the potential for large accidental spills, particularly on the Mackenzie River where barge traffic is relatively heavy.

CHAPTER VIII

WATER USES IN THE STUDY REGION

1. INTRODUCTION

The waters in the Study Region drain from Alberta, Saskatchewan, Manitoba, and portions of British Columbia and the Yukon and Northwest Territories. Each of these jurisdictions exercises certain controls over the use of the water, assigning slightly varying classification schemes for use identification. For the purposes of this study, the following classification of uses is employed:

- irrigation
- other agricultural
- industrial
- municipal
- electric power generation
- recreation
- renewable resource utilization
- transportation

2. IRRIGATION

Irrigation is the greatest consumptive use of water in the Hudson Bay and Missouri drainage regions. It contributes substantially to the growth of crops and is important to the agricultural economy of western Canada. While less than two percent of the cultivated farmland is irrigated, the value of production from this land is high, and crops that could not otherwise be produced are grown.

The farming areas of the Arctic drainage region generally receive ample rainfall during the growing season. Agriculture is restricted by low temperatures rather than moisture. Nonetheless, there are some areas that are irrigated to grow hay, sod, and some vegetables.

A general description of the procedures employed to acquire, distribute, and return water used in irrigation is contained in Chapter VII, along with information concerning land and water quality. A background report by W-E-R Engineering Ltd. (WER, 1980b) provides a brief review of the history of irrigation in the Study Region, and describes the crops grown in the various areas.

In the following, overview summaries of irrigation structure and development are presented for each province. This is followed by specific information concerning present and foreseeable irrigation water uses for each drainage basin. Finally, a summary is made of possible future irrigation developments for this portion of the Study Region, on a provincial basis.

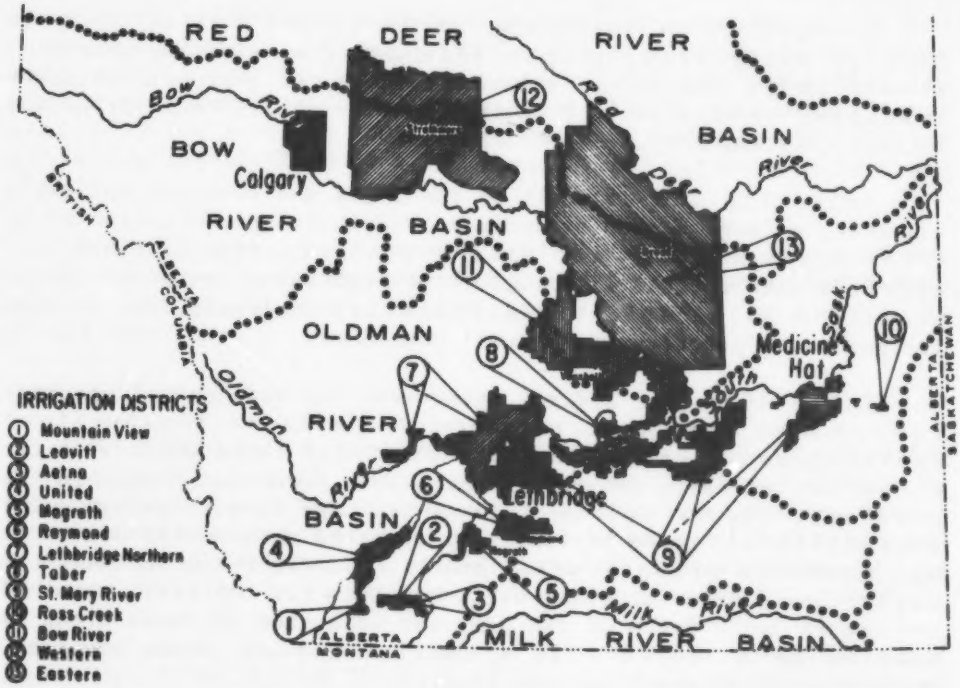
Alberta

In southern Alberta, the first large irrigation projects were initiated in the late 1800s, financed by private companies. Capital works were constructed either by railroad companies or by land development corporations. None of these projects was financially successful, and most were turned over either to the provincial or federal governments or to the farmers.

The Government of Alberta, in 1915, legislated the Irrigation District Act which awarded irrigation districts a quasi-municipal status. In the period 1915 to 1968, a series of Irrigation District Acts was passed which established most of the presently existing districts. In 1968, all former Acts governing irrigation districts were repealed and replaced by the Irrigation Act.

The Irrigation Act details all procedures and conditions concerning irrigation districts. An Irrigation Council administers the Act and any cost-sharing agreements between the province and the operating districts. Each district formed under the provisions of the Act is required to elect a Board of Directors, which establishes an annual water rate each year, approved by the Irrigation Council, to cover the operation and maintenance costs of the district. The Board may also arrange to supply water for purposes other than irrigation, providing that additional users meet the requirements of the Alberta Water Resources Act.

Figure 80. IRRIGATION DISTRICTS IN SOUTHERN ALBERTA (WER, 1980b).


RED DEER RIVER BASIN
Bow River
Red Deer River
BOW RIVER BASIN
Calgary
BRITISH COLUMBIA
ALBERTA
OLDMAN RIVER BASIN
Oldman River
South Sask. River
Medicine Hat
ALBERTA SASKATCHEWAN
Lethbridge
Magrath
Milk River
MILK RIVER BASIN
ALBERTA MONTANA
IRRIGATION DISTRICTS
① Mountain View
② Leavitt
③ Aetna
④ United
⑤ Magrath
⑥ Raymond
⑦ Lethbridge Northern
⑧ Taber
⑨ St. Mary River
⑩ Ross Creek
⑪ Bow River
⑫ Western
⑬ Eastern

There are 13 irrigation districts in Alberta, (Figure 80), all located within basins contributing to the South Saskatchewan River. These districts listed over one million acres (400 000 ha) on their assessment rolls in 1979, of which approximately

900,000 acres (360 000 ha) were irrigated. The distribution of the assessed area by source streams is:

Bow River - 452,000 acres (183 000 ha)
Oldman River - 112,000 acres (45 000 ha)
St. Mary, Belly, and Waterton Rivers - 444,000 acres (180 000 ha)
Ross Creek - 2,000 acres (810 ha)

The Red Deer River is the only large tributary which does not support a major irrigation district. Private irrigation development in Alberta, though widespread, is relatively minor compared with the irrigation districts. Irrigation land represents about six percent of total cropland in the province.

Saskatchewan

Irrigation in Saskatchewan developed initially in the Cypress Hills area, in the southwest corner of the province, around 1890. Located in the heart of the semi-arid Palliser Triangle, this area is primarily cattle country, and irrigation is used to stabilize the feed supply.

Following the drought of the 1930s and over the following decades, a large number of storage reservoirs were constructed by PFRA, and community irrigation projects were developed and operated (see Chapter II.3). This program was accompanied by the provision of technical and financial assistance for private irrigators, a practice which still continues.

Since 1936 the federal government has developed 26 storage reservoirs and six irrigation projects in southwestern Saskatchewan. Canada retains control of these works with the exception of three reservoirs which have been transferred to the province. Water released from storage is also provided for irrigation of seven provincially operated water users districts and numerous private developments. Gardiner Dam on the South Saskatchewan River provides water supplies for the development of irrigated lands north of the Dam, and expansion of these areas is continuing although only a small fraction of the envisaged irrigation development has occurred.

Nearly 200,000 acres (80 000 ha) of land are developed for irrigation in Saskatchewan, of which 36,000 acres (15 000 ha) are within PFRA or provincially sponsored projects, 42 000 acres (17 000 ha) are in the South Saskatchewan River Irrigation

Project and about 120,000 acres (40 000 ha) are in private developments. Between 70 and 80 percent of this land is irrigated in a given year, depending mainly on climatic factors.

Manitoba

Moisture deficiencies in Manitoba generally average less than 15 cm annually. Consequently, irrigation has not assumed the importance in the agricultural economy that it has in the much drier regions of southern Saskatchewan and Alberta where moisture deficiencies can range between 15 cm and 25 cm.

There are no community irrigation projects listed on Manitoba water rights records, and private development, by comparison with its neighboring provinces to the west, is not extensive.

The total irrigated acreage in 1978 was estimated at 11,000 acres (4 500 ha) (Berry, 1979), but this total has increased considerably in the last few years. The Agri-Water Division (Manitoba, Department of Agriculture, 1977) calculated a total area of 9,100 acres (3 700 ha) irrigated by sprinkler in 1977 and estimates the addition of 4,200 acres (1 700 ha) between 1977 and 1980.

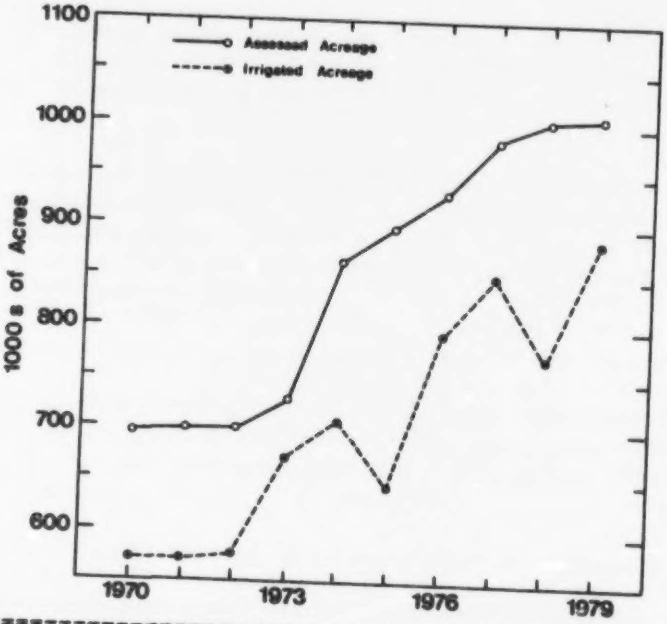
Ground water resources in Manitoba have been developed for irrigation use more intensively than in Alberta or Saskatchewan. A total of 2 200 dam^3 of irrigation demand is supplied by ground water.

Specific Basins

The details of present and foreseeable uses of water for irrigation for each drainage basin are discussed below. It should be noted that trends in irrigation water use throughout these regions reflect not only a variety of economic and technological factors, but also the year-to-year responses of the industry to climatic variations.

For example, a very marked difference in areas irrigated throughout 1977, 1978, and 1979 occurred in the irrigation districts in Alberta. The years 1977 and 1979 were extremely dry, (May-September 1977 precipitation was 60 percent of normal) and total water demands for the irrigation districts reached all-time highs. In 1978, an abnormally wet spring resulted in a later start than usual, and the total irrigation area which actually received water decreased by 80 000 acres (32 000 ha) from 1977. In 1979, the irrigated area rebounded to a record maximum 884 000 acres (358 000 ha). Consumptive use per acre was high in 1977 and 1979 and return flows were low. The change in areas assessed and irrigated in the Alberta irrigation districts (1970-79) is illustrated in Figure 81.

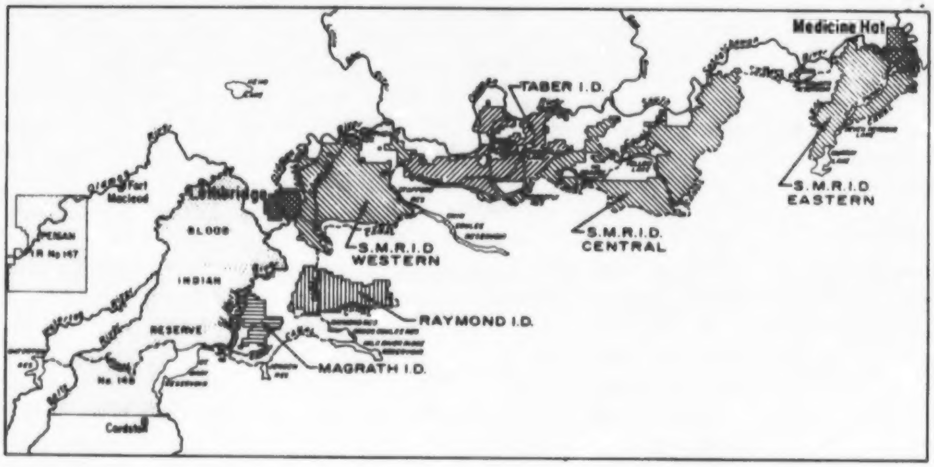
Figure 81. CHANGES IN ASSESSED AND IRRIGATED ACREAGES IN SOUTHERN ALBERTA IRRIGATION DISTRICTS (from WER, 1980b).



Because of the high demand and low supply characteristics of 1977, that year is often used in the following and in the supply/demand analyses of earlier sections, as the basis for evaluating constraints to uses due to supply limitations.

It should also be noted that many licensed irrigation projects have been abandoned or are not operating in accordance with their allocations and that there are some existing projects that are not licensed to withdraw water. Most water rights offices are now actively involved in updating their records, but this is a very time-consuming process. Therefore, despite their inaccuracies, water rights records were the main source of information on private irrigation for this study.

Figure 82. THE ST. MARY PROJECT (WER, 1980b).


Medicine Hat
TABER I.D.
Fort Macleod
Lethbridge
PEIGAN
I.R. No 147
BLOOD
INDIAN
RESERVE
No 148
Cardston
S.M.R.I.D WESTERN
S.M.R.I.D. CENTRAL
S.M.R.I.D EASTERN
RAYMOND I.D.
MAGRATH I.D.

Oldman River Basin

The Waterton, Belly, and St. Mary Rivers all originate in the United States, are major tributaries to the Oldman River, and are the principal sources of supply for the St. Mary Irrigation Project (Figure 82). The main supply canal extends approximately 400 kilometres from the Waterton Reservoir on the Waterton River to its termination near Medicine Hat, providing water to the St. Mary River, Magrath, Raymond, and Taber Irrigation Districts. Eleven communities with a total population of nearly 9000 are also supplied approximately 3500 dam^3 of water annually from the canal system for municipal use.

System reservoirs provide a total live storage of approximately 826 000 dam^3. Onstream storage is in the Waterton Reservoir and the St. Mary Reservoir, while Milk River Ridge Reservoir and Chin Reservoir are the major offstream storage facilities. Downstream from Chin Reservoir, additional storage is supplied by eight smaller reservoirs. The capacities of major reservoirs and main canals are contained in Table 55. Return flows drain to the St. Mary, Oldman, and South Saskatchewan Rivers.

TABLE 55. STORAGE RESERVOIRS IN THE OLDMAN RIVER BASIN

I.D. - MAIN CANAL CAPACITY	MAIN RESERVOIRS	LIVE STORAGE (DAM^3)
ST. MARY PROJECT - 90 M^3/S	WATERTON RES.	100 000
	ST. MARY RES.	352 000
	MILK RIVER RIDGE RES.	118 000
	CHIN RES.	173 000
	TABER LAKE	5 600
	HORSEFLY LAKE	8 400
	FINCASTLE LAKE	3 300
FOOTHILLS DISTRICTS - UID: 7.4 M^3/S - OTHERS 4.2 M^3/S	COCHRANE LAKE	3 700
	PAINE LAKE	8 600
LNID - 18.4 M^3/S(1)	KEHO LAKE	47 000 (2)
PRIVATE	CHAIN LAKES RES.	16 400

1. ORIGINALLY DESIGNED AT 25 M^3/S, BUT THERE HAS BEEN SETTLEMENT ON ONE FLUME.

2. STORAGE IN KEHO LAKE IS TO BE RAISED TO 86 000 DAM^3 BY 1985. WORK IS NOW IN THE DESIGN STAGE.

Three principal blocks of land make up the St. Mary River Irrigation District (SMRID): the western block in the vicinity of Lethbridge, the central block in the Burdett-Bow Island area, and the eastern block in the vicinity of Medicine Hat.

The SMRID western block is situated below Milk River Ridge Reservoir and obtains water via a turnout from the St. Mary main canal. The central and eastern blocks are situated downstream of Chin Reservoir. The central block receives water from turnouts on the main canal supplemented by releases from Grassy Lake reservoir. The eastern block is supplied from the main canal as well as Murray, Sauder, and Seven Persons Reservoirs.

The Magrath Irrigation District (MID) is located approximately 50 kilometres southwest of Lethbridge. A headgate located on the St. Mary main canal about five kilometres downstream from the St. Mary Reservoir provides the major water supply, and Spring Coulee Reservoir on the St. Mary Canal is a secondary supply source. The district does not have any internal storage capability.

Two turnouts on the St. Mary main canal southeast of Raymond supply water to the Raymond Irrigation District (RID). Water is carried east and west from these turnouts in two main laterals. The RID also contains no storage reservoirs.

The Taber Irrigation District (TID), one of the oldest districts in the province, is located east of Lethbridge between the Oldman River and the St. Mary Main Canal, the latter supplying water to the project. There are three main internal reservoirs on the TID: Taber Lake which was constructed to impound wastewater from the project; Horsefly Lake which provides water for peaking purposes; and Fincastle Lake.

To date, storage capacity in the St. Mary Project has been sufficient to accommodate most demands in low-streamflow years such as 1944 and 1977, permitting a fairly steady increase in assessed irrigated acreage to the present total of more than 400,000 acres (160 000 ha). The eastern end of the system, however, experiences periodic shortages, and a moratorium was imposed in 1974 (still in effect) on the development of any further irrigated land downstream of Chin Reservoir. Water shortages in 1977 resulted in cutbacks on the area of land which could be supplied during the peak months.

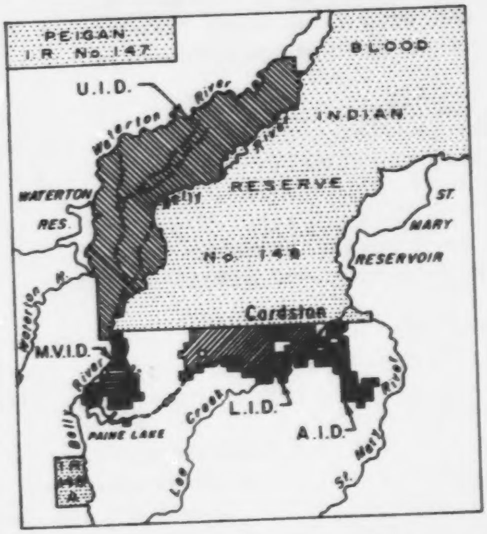
The Belly River also supplies water to the United, Mountain View, Leavitt, and Aetna Irrigation Districts (Figure 83).

The United Irrigation District (UID), located southwest of Fort Macleod between the Waterton and Belly Rivers, receives water by diversion from the Belly River at a location about 10 kilometres south of Hill Spring. The main canal conveys water northward from the diversion point to Cochrane Lake Reservoir (see Table 56). Gravity irrigation is not considered economical because of the rough terrain within the District, and flooding or sprinkler systems are used for applying water to the land.

The irrigated area on the assessment roll has not changed significantly in the last 20 years, remaining at about 34,000 acres (14 000 ha). The principal constraints to expansion of the district are unsuitable terrain and the fact that the water available in the Belly River can be more efficiently utilized on the St. Mary Project.

The Mountain View (MVID), Leavitt (LID), and Aetna (AID) Irrigation Districts are small districts supplied from diversion works on the Belly River near Mountain View. Water is conveyed by canal from Paine Lake, the only significant storage reservoir in the system. From Paine Lake, the canal supplies the MVID and LID, then crosses Lee Creek by a syphon, terminating at the AID.

Figure 83. THE FOOTHILLS IRRIGATION DISTRICTS (WER, 1980b).


PEIGAN I.R. No. 147
BLOOD INDIAN RESERVE No. 148
U.I.D.
Waterton River
Belly River
WATERTON RES.
ST. MARY RESERVOIR
Waterton R.
Cardston
M.V.I.D.
River
Belly
PAINE LAKE
Lee Creek
L.I.D.
A.I.D.
St. Mary River
I.R.
A.

The total area on the assessment rolls of the MVID, LID, and AID has not changed appreciably in recent years, remaining at about 11,000 acres (4 300 ha). Increases in irrigated areas have been constrained for the same reasons as outlined for the UID - rough topography which results in rather inefficient use of the water, and demands for Belly River water in the St. Mary system. The AID and the LID have some potential for expansion, but the present main supply system capacity would not permit large increases in irrigated acreages, and enlargement of the canal system is not under consideration at present.

The Lethbridge Northern Irrigation District (LNID), the only major project supplied directly from the Oldman River, is located northwest of Lethbridge (Figure 84), encompassing 205,000 acres (83 000 ha), half of which is included in the district assessment rolls. Water is supplied from a diversion weir on the Oldman River west of Fort Macleod within the Peigan Indian Reserve. The main canal extends from the diversion works to Keho Lake, the only storage reservoir of significance in the LNID supply system (see Table 55). Water is conveyed to the district by two major lateral canals: the Monarch Lateral, which is fed from a headgate on the main canal upstream of Keho Lake, and the Turin Lateral, supplied from the Turin Headworks at the east end of Keho Lake. Almost 65,000 acres (26 300 ha) of land in the LNID

TABLE 56: DISTRICT IRRIGATION IN THE OLDMAN RIVER BASIN - 1977
(WER, 1980B; EC, 1978D, 1979A, 1980C)

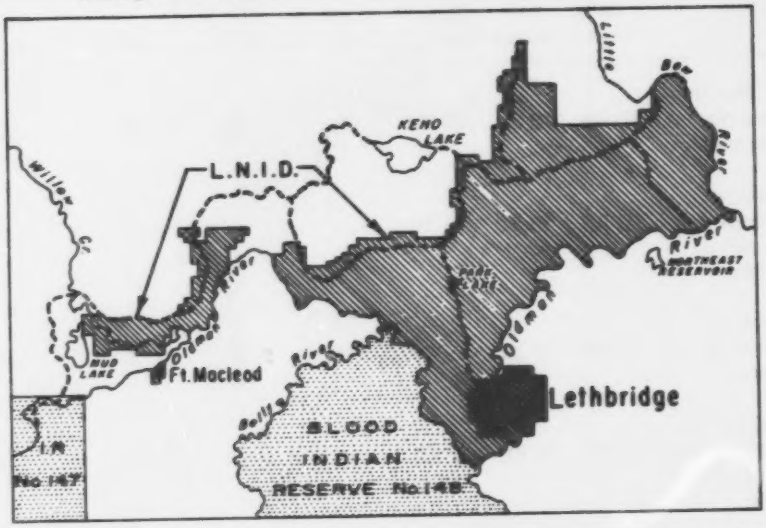
IRRIGATION DISTRICT	AREA ASS'D (ACRES)	AREA IRR'D (ACRES)	TOTAL DIVERSION (DAM^3)	PERCENT RETURNED (%)	RETURN FLOW (DAM^3)	CONSUMPTION (DAM^3)	CONSUMPTION PER ACRE (DAM^3/AC.)
St. Mary River Irrigation District**	383 600	342 000	615 300	13	77 500	537 800	1.57
Lethbridge Northern Irrigation District	111 700	99 300	208 800	9	18 700	190 100	1.91
United Irrigation District	33 600	33 300	38 200	44	16 900	21 300	0.64
Mountain View & Leavitt-Aetna Irrigation District	11 200	10 400	32 900	43	14 100	18 900	1.80
Total:	540 100	485 000	895 200	14	127 200	768 100	1.58

** Includes MID, RID, and TID.

are under gravity irrigation, and a further 45,000 acres (18 200 ha) are irrigated by sprinkler systems. All return flows from the LNID drain to the Little Bow or Oldman Rivers. The system also supplies 500 dam^3 annually for municipal use to several communities.

The water supply available in the District is exceeded by demand for a short period (five to ten days) in many years, and in 1974 the LNID Board declared a moratorium on any further development. Since the District has no headworks storage, it must depend almost entirely on the natural flow in the Oldman River for its supply. In 1977, flows in the Oldman River near the LNID diversion exceeded the designed capacity of the diversion canal (25 m^3/s) in only 60 days through the entire year. Although the effective capacity of the canal is somewhat less, it is clear that its diversion potential cannot be realized in low-flow years. Riparian demands require that adequate flows be maintained downstream from the diversion works, which further limits the water available to the LNID. As a result, the District was forced to restrict irrigation use on at least two occasions during times of peak demand in 1977, and again in 1979.

Figure 84. THE LETHBRIDGE NORTHERN IRRIGATION DISTRICT (LNID), (WER, 1980b).


Little
Bow
River
KENO LAKE
L.N.I.D.
Willow Cr.
River
Northeast Reservoir
Park Lake
Oldman
Oldman River
Mud Lake
Ft. Macleod
Belly River
Lethbridge
BLOOD INDIAN RESERVE No.148
I.R. No.147

Statistics of irrigated acreages on assessment rolls, acreages irrigated, and water use for recent years in the nine districts supplied from the Oldman River basin are contained in Tables 57, 58 and 59.

Recently licensed private projects in the Oldman River basin are almost entirely based on sprinkler-type operations, the majority being centre pivot systems. According to the Water Rights Branch of Alberta Environment, 430 irrigation projects in the Oldman River Basin were under private license in 1980, with a total irrigated area of 50,000 acres (20 200 ha). The water allocation is 89 900 dam^3, and the aggregate privately-owned reservoir capacity is 10 500 dam^3.

Of the total private demand, 11 800 dam^3 are presently licensed in the Willow Creek basin, supplying 7,000 acres (2800 ha). Chain Lakes Reservoir, located on the upper reaches of the stream, has a storage capacity of 16 400 dam^3, but is heavily utilized for recreation purposes, and presently has very limited use as an irrigation supply source. Additional storage capacity available for private irrigation totals only 1200 dam^3, all of which is in small, privately owned reservoirs located on tributaries.

TABLE 57: DISTRICT IRRIGATION IN THE OLDMAN RIVER BASIN - 1978
(AER, 1980b; EC. 1978d, 1979a, 1980c)

IRRIGATION DISTRICT	AREA ASS'D (ACRES)	AREA IRR'D (ACRES)	TOTAL DIVERSION (DAM^3)	PERCENT RETURNED (%)	RETURN FLOW (DAM^3)	CONSUMPTION (DAM^3)	CONSUMPTION PER ACRE (DAM^3/AC.)
ST. MARY RIVER IRRIGATION DISTRICT**	395 300	293 900	282 900	24	67 700	215 100	0.73
LETHBRIDGE NORTHERN IRRIGATION DISTRICT	111 900	73 400	105 900	24	25 100	80 800	1.10
UNITED IRRIGATION DISTRICT	33 700	8 700	13 100	69	9 000	4 100	0.48
MOUNTAIN VIEW & LEAVITT-AETNA IRRIGATION DISTRICT	11 300	11 200	8 000	56	4 500	3 600	0.32
TOTAL:	552 200	387 200	409 900	26	106 300	303 600	0.78

** INCLUDES MID, RID, AND TID.

TABLE 58: DISTRICT IRRIGATION IN THE OLDMAN RIVER BASIN - 1979
(AER, 1980b; EC. 1978d, 1979a, 1980c)

IRRIGATION DISTRICT	AREA ASS'D (ACRES)	AREA IRR'D (ACRES)	TOTAL DIVERSION (DAM^3)	PERCENT RETURNED (%)	RETURN FLOW (DAM^3)	CONSUMPTION (DAM^3)	CONSUMPTION PER ACRE (DAM^3/AC.)
ST. MARY RIVER IRRIGATION DISTRICT**	399 500	350 400	552 900	14	75 200	477 800	1.36
LETHBRIDGE NORTHERN IRRIGATION DISTRICT	111 900	115 800	171 000	10	16 500	154 500	1.34
UNITED IRRIGATION DISTRICT	33 500	32 800	25 200	62	15 600	9 700	0.30
MOUNTAIN VIEW & LEAVITT-AETNA IRRIGATION DISTRICT	11 300	11 200	16 000	60	9 600	6 400	0.57
TOTAL:	556 200	510 200	765 100	15	116 900	648 400	1.27

** INCLUDES MID, RID, AND TID

TABLE 59. IRRIGATION DEVELOPMENT IN THE OLDMAN RIVER BASIN
000S ACRES (000S HA)

	1979		1990		MAXIMUM WITH AVAILABLE WATER	
LNID	110	(45)	130-140	(53-57)	170-180	(69-73)
ST. MARY PROJECT	400	(162)	460-480	(186-194)	600	(243)
FOOTHILLS DISTRICTS	45	(18)	45-50	(18-20)	60	(24)
PRIVATE	50	(20)	60-80	(24-32)	80+	(32+)
TOTAL	605	(245)	695-750	(280-305)	900+	(370+)

Presently licensed private irrigation usage in the Little Bow basin, including Mosquito Creek but excluding McGregor Lake drainage, total 11 400 dam^3 annually, which supplies 9,100 acres (3700 ha). The only significant storage in this basin is in Travers Reservoir, which is part of the Alberta Environment headworks serving the Bow River Irrigation District and, as such, contributes little to flow improvement downstream. Water is diverted into the Little Bow from the Highwood River, but the diversion quantities are relatively small.

Most of the private licensed projects that rely on the main stem of the Oldman River are located far enough downstream to derive some benefit from return flows from the irrigation districts, which enhance supply through much of the growing season. Nonetheless, there are times in the year when flows are not adequate to supply all demands, including the need to maintain a minimum flow. On smaller tributary streams where no storage facilities exist, shortages frequently occur during the summer months.

In 1980, the Water Rights Branch suspended approval of new private licenses throughout the Oldman River basin, pending the development of new issuing guidelines. When issued, new licenses will be subject to restrictions, especially regarding the time of year when water may be withdrawn. Many applications await processing, especially regarding further development in the Willow Creek and Little Bow River basins, but the water supply in these areas is approaching full allocation. During 1977, the total flow in Willow Creek near the mouth was about 5000 dam^3 from May to August inclusive, which is only sufficient to meet approximately one-half of the irrigation demand. Additional reservoir sites in the Little Bow River basin have been investigated, and these could substantially improve water supplies during the irrigation season assuming that the diversion from the Highwood River could be increased.

Constraints to future irrigation development in the Oldman River basin are due to unreliable water supplies, jurisdictional commitments, and the inability of works to store and deliver the required amounts of water when needed. Climatic conditions are very good, soils are highly fertile, and the major natural constraint to growth of agricultural crops is the low growing-season precipitation. Many areas are thus particularly suited to irrigation development as a means of making up the moisture deficit. Presently available water supplies, however, are taxed to the limit in serving the nine irrigation districts.

The major jurisdictional constraint to irrigation development in the Oldman, Bow, and Red Deer River basins is the 1969 Prairie Provinces Water Board Agreement on Apportionment (see Chapter I.7). This agreement entitles Alberta to consume, divert, or store for its consumptive use in any one year a quantity of water equal to one-half the natural flow of the South Saskatchewan River entering Saskatchewan, but adds that Alberta is entitled to a minimum of 2 600 000 dam^3 from the river annually, provided that by doing so, it does not reduce the actual flow at the boundary to less than 42 m^3/s, or one-half of the natural flow. The flow of the three rivers (plus the contribution from the Alberta portion of the South Saskatchewan River basin) must combine to meet these requirements. The only year to date that this agreement has had any real effect on operation of the irrigation districts was in 1977, when some of the districts were required to cut back on diversions. This agreement could, however, be a significant constraint to future expansion of irrigated areas.

Other jurisdictional commitments also limit water available for irrigation. The St. Mary River is an international stream, subject to the provisions of the 1909 Boundary Waters Treaty and the 1921 Apportionment Order of the International Joint Commission. This order, as it affects the St. Mary system, states that at the border Canada is entitled during the irrigation season to three-quarters of the natural flow that is less than 666 cfs (18.9 m^3/s), plus one-half the natural flow above that figure. This provision limits the amount of water available to the St. Mary Project. The Belly and Waterton Rivers are also international streams but, unlike the St. Mary River, are not subject to an apportionment agreement. They traverse very mountainous areas in the United States, however, and most of their waters are therefore available for use in Canada.

Future development of irrigation in the Oldman River basin has been the subject of extensive study and public discussion since 1974 when the planning, management, and construction of irrigation works came under provincial administration. Alberta Environment began initial planning studies (Phase I) in that same year, and more comprehensive (Phase II) studies were initiated in 1976. The Oldman River Study Management Committee (ORSMC), formed to guide Phase II, presented its recommendations in a report entitled Oldman River Final Report(1978). Concurrently, the Environment Council of Alberta (ECA) was asked to hold public hearings on the management of water resources within the Oldman River Basin.

The ORSMC recommended development in three phases, involving rehabilitation and enlargement of canals, enlargement and construction of offstream reservoirs, and construction of a multipurpose flow regulation reservoir on the Oldman River, at a total cost of about $325 million (1978). The ORSMC suggested that the total irrigated acreage in the Oldman River basin (including that land which lies within the South Saskatchewan River basin but is irrigated with water from the Oldman River or its tributaries) be allowed to increase to:

650 000 acres (260 000 ha) by 1985,
750 000 acres (300 000 ha) by 1990, and
850 000 acres (340 000 ha) by 2005.

However, it was noted that development to this ultimate level is contingent upon the option selected for the management of the flow of the Bow and Red Deer Rivers with respect to apportionment of the flow of the South Saskatchewan River (mentioned earlier). The proposed sequence of development presupposes a contribution of 75 percent of the natural flow of the Red Deer River and 50 percent of the natural flow of the Bow River. If the allocation were set at 50 percent of the flow from each of the three rivers, irrigation development in the Oldman River basin would be limited to:

a) somewhat less than 700,000 acres (280 000 ha) without onstream storage (ECA, 1979c), and

b) less than 800,000 acres (320 000 ha) with onstream storage (ORSMC, 1978).

The Environment Council of Alberta made slightly different recommendations. They proposed rehabilitation of the irrigation water delivery systems "with all reasonable speed", but rejected some of the reservoirs and a major pumping station on economic grounds. The facilities that were recommended by the ECA (1979c) would allow the areas irrigated to increase to the following levels:

	000s acres	(000s ha)
LNID	170	(69)
St. Mary's Project	465	(188)
Foothills District	47	(19)
Private Onstream	74	(30)
Total	756	(306)

Total cost was estimated at $151 million (1979).

In September of 1980, the Alberta Ministers of Environment and Agriculture announced their decision on water and irrigation development in southern Alberta, based on the above recommendations and those of the Caucus Committee on Water Resources. Projects approved, pertaining to the Oldman River basin, closely followed the recommendations of the ORSMC, rather than those of the ECA. The total cost was estimated to be about $190 million dollars plus funds from Alberta Agriculture for irrigation works improvement; but this amount did not include funding for the enlargement of Chin Coulee Reservoir, nor the construction of Chin Pump, Mud Lake Reservoir, and a dam on the Oldman River, although these projects were approved. "Any dam would not be operational until the 1990s and in terms of costs today would require approximately $140 million" (Cookson and Schmidt, 1980).

Working from the projections of the ECA and the ORSMC based on their proposals for additional irrigation works, and taking into account the decision by Alberta regarding the construction of works, it is possible to estimate the foreseeable increase in the irrigated area of the Oldman River basin. Table 59 presents a summary of present and estimated future assessed irrigated areas within irrigation districts, along with estimates of the maximum area that could be irrigated with the water available in the basin. The information is supported by officials of Alberta Environment and Alberta Agriculture.

These estimates assume that the Red Deer and Bow Rivers will contribute 75 percent and 50 percent of their flows respectively to apportionment, that the economic and political structure in the region will not change drastically, and that experienced manpower will be available.

Alberta Agriculture has estimated that there are approximately 1,250,000 acres (500 000 ha) of irrigable land "within easy access of existing irrigation development" (ORSMC, 1978), so it appears that the land development potential exceeds the maximums listed above. Only in the LNID is there "more water than land that can be brought under irrigation at reasonable cost" (ECA, 1979c), but there is considerable land adjacent to the LNID that could be developed. Pedology Consultants (1980) estimated that a total of 2,140,000 acres (866 000 ha) are actually developable in the Oldman River basin, although much of this land has only a low or moderate need for water based on climate. On the other hand, the estimate does not include land in the South Saskatchewan River basin that could be irrigated with water from the Oldman River basin. UMA (1981) estimated that a total of 2,270,000 acres could be irrigated in the basin. Development beyond 1990 will clearly depend on the policy that is established regarding the apportionment of flows from each of the Oldman, Bow, and Red Deer River basins. The South Saskatchewan River Basin Planning Program recently initiated by Alberta Environment is designed to provide a framework plan for the management of water in these three basins.

TABLE 60. STORAGE RESERVOIRS IN THE BOW RIVER BASIN

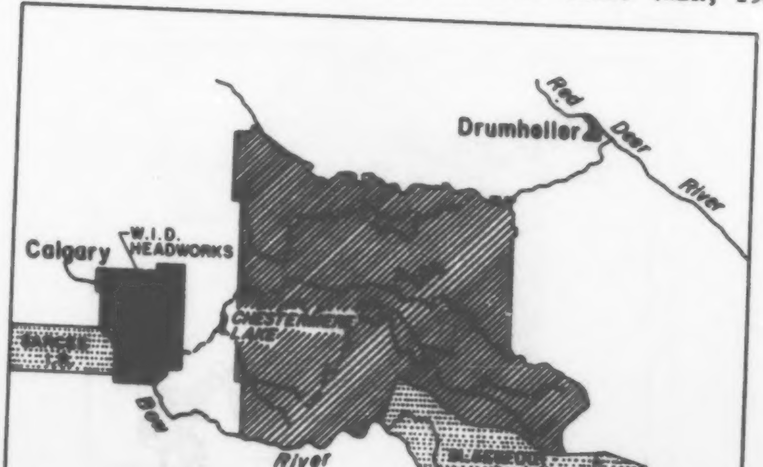
I.D. - MAIN CANAL CAPACITY	MAIN RESERVOIRS	LIVE STORAGE (DAM^3)
W.I.D. - 25 m^3/s	Chestermere Lake	6 000
	Langdon Res.	7 600
BRID - 38 m^3/s	Lake McGregor	322 000
	Travers Res.	105 000
	Little Bow Res.	21 000
	Scope Res.	15 000
E.I.D. - 113 m^3/s	Lake Newell	232 000

Bow River Basin

The Bow River provides water for a number of uses such as hydro-electric power generation, municipal and industrial supplies, and recreation, but by far the largest consumptive use of water is for irrigation purposes. The predominant users are the Western Irrigation District (WID), the Bow River Irrigation District (BRID), and the Eastern Irrigation District (EID) (Figure 80). The capacities of major reservoirs and main canals are contained in Table 60. Portions of these districts are located in the natural drainage areas of the adjacent Red Deer and Oldman Rivers, so that water is transferred from the Bow River to those rivers as irrigation return flows.

The construction of the Western Irrigation District (WID) (Figure 85) was initated by the Canadian Pacific Railway (CPR) in 1903, and the main diversion works, located within the City of Calgary, were completed by 1911. From the headworks, a canal runs generally easterly for some 21 kilometres to Chestermere Lake, which serves as a balancing pond that feeds two secondary canal systems. Langdon Reservoir provides some additional storage. The District is approximately 56 kilometres square, and encompasses 1,022,000 acres (414 000 ha), though less than 10 percent of this land is on the assessment rolls. An estimated 60 percent of the return flow drains to the Bow River, with the remaining 40 percent reaching the Red Deer River.

Figure 85. THE WESTERN IRRIGATION DISTRICT (WID) (WER, 1980b).

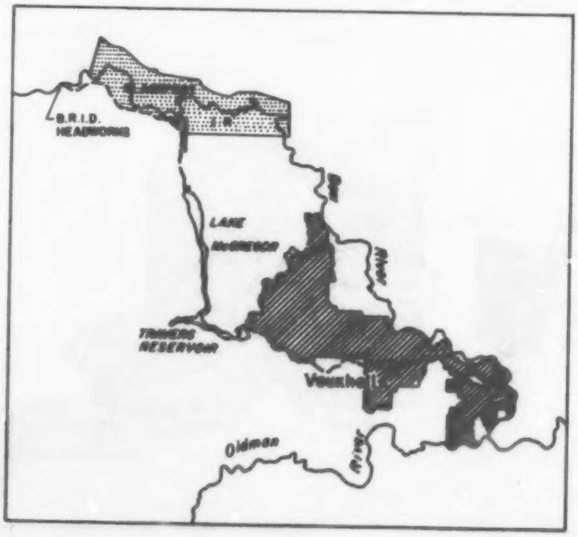


The Western Irrigation District has no headwork storage and must therefore rely on direct river flows for its irrigation supply. It experienced shortages to its main supply canal in 1977 and is forced to cut back on irrigation during critical low-flow periods. This situation can only deteriorate if the district continues to expand its irrigated area.

The Bow River Irrigation District (BRID) (Figure 86) headworks and main supply system were constructed by the Canada Land and Irrigation Company between 1914 and 1920. Water is supplied to the District via a diversion weir on the Bow River near Carseland. The main canal extends some 66 kilometres from the weir to Lake McGregor, then flows into Travers Reservoir, and finally into the Little Bow Reservoir, which releases water into the distribution system. These three reservoirs have a combined capacity of approximately 450 000 dam^3. Additional internal storage is provided for the downstream section of the district by the Scope Reservoir.

From Little Bow Reservoir, the canal splits into two main branches, the Lomond lateral which supplies the northern section of the district, and the main canal which provides water to the southern and eastern sectors. The BRID also supplies water to six communities. Eighty percent of the return flow from the BRID is released to the Bow River, with 20 percent draining to the Oldman River.

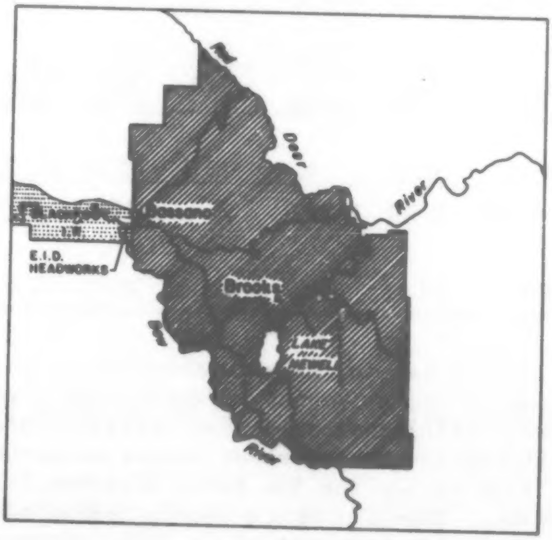
Figure 86. THE BOW RIVER IRRIGATION DISTRICT (BRID) (WER, 1980b).



The BRID is not as directly dependent on river flows as is the WID. However, the amount of water which can be diverted into storage during the frost-free diversion period in any year is constrained by the capacity of the canal from the diversion weir at Carseland to Lake McGregor. When demands are heavy in a dry year, the district has trouble building up much reserve storage. The problem is compounded in low-flow years, such as 1977 when diversion into the main canal at Carseland was reduced to 50 percent of the canal capacity during the peak irrigation season. The BRID has a moratorium on development beyond 175,000 acres (70 000 ha). In 1979 there were 150,000 acres (61 000 ha) on the assessment roll.

The project now called the Eastern Irrigation District (EID) (Figure 87) was initated by the CPR with the construction of Bassano Dam and canal headworks on the Bow River near Bassano in 1912. The project was operated by the CPR until 1935, when the land and irrigation works in what was then called the East Block were transferred to local farmers, and the EID was formed. The total area within the boundaries of the district is in excess of one million acres (400 000 ha), with about one-quarter being on the district assessment rolls. The District also supplies the municipal water requirements of a number of communities including Brooks and Bassano.

Figure 87. THE EASTERN IRRIGATION DISTRICT (EID) (WER, 1980b).



Bassano dam has deteriorated during its almost 70 year life, and has just undergone extensive repair. This will extend the life of the dam about 10 years, but major reconstruction has been delayed because of uncertainty over ownership of the river bed under the dam.

Until recently the only significant storage in the EID was Lake Newell, whose full supply level has been recently increased by nearly 50 percent (Table 60). Because of its location near the downstream end of this project, however, the storage in Lake Newell is available to only part of the District. An estimated 30 percent of irrigation return flow drains to the Bow River, with the remainder flowing to the Red Deer River.

TABLE 61: DISTRICT IRRIGATION IN THE BOW RIVER BASIN - 1977
(WER, 1980B; EC, 1978D, 1979A, 1980C)

IRRIGATION DISTRICT	AREA ASS'D (ACRES)	AREA IRR'D (ACRES)	TOTAL DIVERSION (DAM^3)	PERCENT RETURNED (%)	RETURN FLOW (DAM^3)	CONSUMPTION (DAM^3)	CONSUMPTION PER ACRE (DAM^3/AC.)
WESTERN IRRIGATION DISTRICT	68 500	48 500	169 000	28	47 000	122 000	2.52
BOW RIVER IRRIGATION DISTRICT	147 800	131 400	370 800	33	123 500	247 300	1.89
EASTERN IRRIGATION DISTRICT	225 000	208 800	705 500	20	138 300	567 200	2.71
TOTAL	441 300	388 700	1245 300	25	308 800	936 500	2.41

The district has not experienced serious water shortages to date. However, a recent review of water supply and management in the EID (UMA, 1977) indicated that irrigated acreages could not expand significantly above present levels unless storage capacity within the EID or on the Bow River upstream from the headworks were provided. The district declared a moratorium on the development of new irrigation in 1974, although the irrigated area in the District has continued to increase as a result of

TABLE 62: DISTRICT IRRIGATION IN THE BOW RIVER BASIN - 1978
(WER, 1980b; EC, 1978d, 1979a, 1980c)

IRRIGATION DISTRICT	AREA ASS'D (ACRES)	AREA IRR'D (ACRES)	TOTAL DIVERSION (DAM^3)	PERCENT RETURNED (%)	RETURN FLOW (DAM^3)	CONSUMPTION (DAM^3)	CONSUMPTION PER ACRE (DAM^3/AC.)
WESTERN IRRIGATION DISTRICT	71 600	33 300	127 100	58	73 100	53 900	1.62
BOW RIVER IRRIGATION DISTRICT	153 100	130 000	256 300	38	97 800	158 600	1.22
EASTERN IRRIGATION DISTRICT	227 200	204 200	476 800	27	130 400	346 400	1.70
TOTAL:	451 900	367 500	860 200	35	301 300	558 900	1.52

TABLE 63: DISTRICT IRRIGATION IN THE BOW RIVER BASIN - 1979
(WER, 1980b; EC 1978d, 1979a, 1980c)

IRRIGATION DISTRICT	AREA ASS'D (ACRES)	AREA IRR'D (ACRES)	TOTAL DIVERSION (DAM^3)	PERCENT RETURNED (%)	RETURN FLOW (DAM^3)	CONSUMPTION (DAM^3)	CONSUMPTION PER ACRE (DAM^3/AC.)
WESTERN IRRIGATION DISTRICT	74 500	46 600	170 600	28	48 500	122 100	2.62
BOW RIVER IRRIGATION DISTRICT	150 200	133 500	319 900	32	101 600	218 300	1.63
EASTERN IRRIGATION DISTRICT	227 300	213 800	669 500	25	170 500	499 100	2.34
TOTAL:	452 000	393 900	1160 000	28	320 600	839 500	2.13

intensification on lands having previous water agreements. The provision of adequate internal storage would permit expansion to an upper limit of about 285,000 acres (115 000 ha) (Alberta Environment 1972, 1977b) (UMA, 1977).

Statistics of irrigated acreages on assessment rolls, acreages irrigated, and water use for recent years in the district supplied from the Bow River basin are contained in Tables 61, 62 and 63.

Private irrigation development in the Bow River basin is minor compared to the irrigation districts. Flows in the river are quite reliable (except downstream of Bassano Dam), and private projects supplied from the main stem of the river do not generally experience shortages. During the summer of 1977, however, the EID diverted all flows over 3 m^3/s and users below Bassano Dam were adversely affected. Some benefit is derived from return flows which stabilize sections of the main river and those tributary streams which are utilized as drainage channels. Excessive plant growth caused by nutrients released from the sewage treatment plants in Calgary causes clogging of pumping facilities operating from the Bow River.

The total licensed private irrigation demand in the basin is 43 000 dam^3. The area under irrigation is 29,000 acres (11 800 ha), and the storage capacity is 2500 dam^3. No restrictions on further private development are foreseen in the near future.

As in the Oldman River basin, the major natural constraint to the growth of crops in the Bow River basin is due to the low growing-season precipitation, which accounts for the widespread practice of irrigation. Irrigation development, however, is constrained by unreliable water supplies, jurisdictional commitments, and the capacity of existing storage and conveyance systems.

The decisions made by the Alberta Ministers of Environment and Agriculture in September,1980 (described earlier) regarding irrigation development in southern Alberta will help to increase the reliable supplies of water to the irrigation districts. Alberta Environment will fund canal and headworks improvements in all three districts (at a cost of about $35 million) and development of offstream storage in the EID and the BRID. Alberta Agriculture will expend additional funds to improve smaller irrigation works.

The Oldman River Study Management Committee (1978) estimated 550,000 irrigated acres (220 000 ha) by 1985 in irrigation districts served with water from the Bow River. Alberta Agriculture, Irrigation Division still supports this estimate (see Table 64).

Table 64. IRRIGATION DEVELOPMENT IN THE BOW RIVER BASIN

000s acres (000s ha)

	1979	1985	MAX. WITH AVAIL. WATER	TOTAL IRRIGABLE LAND
BRID	150 (61)	200 (81)	250 (101)	350 (142)
EID	225 (91)	250 (101)	340 (138)	400 (162)
WID	75 (30)	100 (40)	150 (61)	200 (81)
Private	30 (12)	---	---	---
Total:	480 (194)	550+ (222+)	740+ (300+)	950+ (385+)

It also suggests that the assessed acreage could eventually increase to about 740,000 acres (300 000 ha) with appropriate storage and conveyance facilities. Alberta Environment estimates that the maximum area that could be irrigated without any limitations in water supply is nearly one million acres (400 000 ha). Pedology Consultants (1980) indicated that a total of 1,125,000 acres (455 000 ha) within the Bow River basin irrigation districts, plus over 500,000 acres outside the districts, are "actually developable". UMA (1981) estimated a total "commandable" area of nearly 2.5 million acres in the basin. If the irrigated acreages in the districts are increased substantially, future restrictions could be imposed on private irrigation.

The total amount of water that can be diverted for irrigation use will ultimately be limited by the Apportionment Agreement. At the estimated 1985 level of development, for example, the residual flow of the Bow River allocated to apportionment would equal 70 percent of its natural flow in a wet year and 50 percent in a dry year (ORSMC, 1978). Further development in the Bow River basin could limit water use in the Oldman and Red Deer Rivers during dry years in order that apportionment requirements are met.

Red Deer River Basin

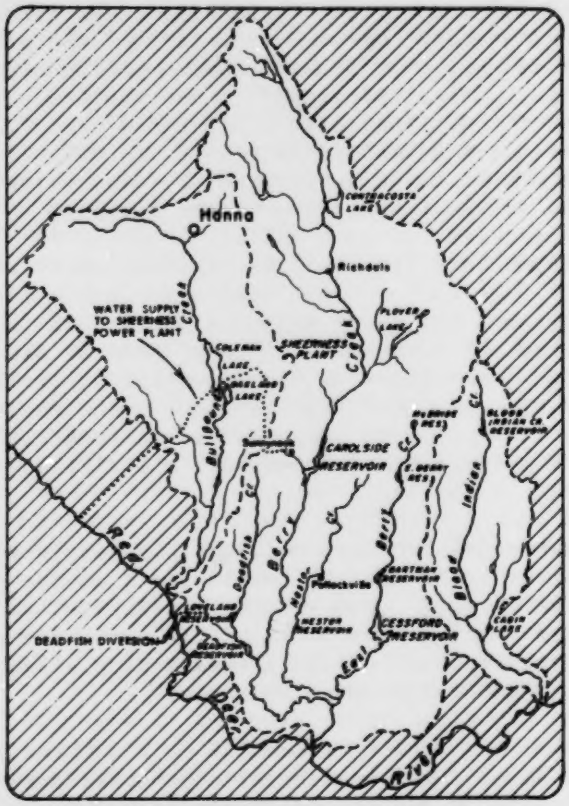
The upper reaches of the Red Deer River basin are located in mountainous or foothills areas with higher precipitation rates and generally lower average temperatures than occur in the more southerly river basins. As a result, irrigation in this portion of the basin is minimal. Downstream from the city of Red Deer, however, the basin includes a large region of low rainfall and relatively high summer temperatures, where private irrigation areas have been developed, and where water supplies are crucial to the success of the cattle industry. Much of this part of the basin is irrigated as part of the Western and Eastern Irrigation Districts which are supplied from the Bow River. In stretches of the river valley where exposure to the sun is favorable, market gardening has begun, with water being pumped directly from the river. North of the river, downstream from Drumheller in a region known as the Special Areas, a number of tributaries are the source of water for private irrigation.

The total privately licensed irrigation demand in the Red Deer River basin is 44 700 dam^3 annually, and the total area irrigated is 32,600 acres (13 200 ha). The present storage capability along the Red Deer River totals 1700 dam^3 in privately owned reservoirs, and a further 3800 dam^3 in reservoirs operated by the Special Areas Board.

In spite of the lack of onstream reservoir storage, water supplies in the river during the irrigation season have generally been ample, and no serious shortages of water for private irrigation have been experienced for those projects supplied directly from the river. In the case of the Special Areas, however, there is a long history of water supply and management problems which have intensified significantly in recent years.

A detailed study of water supply, management, and use by the Planning Division of Alberta Environment is now nearing completion. Phase I of this study specifically deals with the Berry, Blood Indian, and Bullpound Creek basins (Figure 88). The water use portion of the study indicates that in addition to the 575 licensed projects (irrigation and domestic) identified, a further 200 unlicensed projects were in operation (Alberta Environment, 1979a). Twelve community storage reservoirs with an aggregate storage capacity of 41 000 dam^3 are in service, all constructed originally by the Prairie Farm Rehabilitation Administration (PFRA) mainly for irrigation or stock water purposes.

Figure 88. THE BERRY, BLOOD INDIAN, AND BULLPOUND CREEK DRAINAGE BASINS (WER, 1980b).


Hanna
Contracosta Lake
Richdale
Plover Lake
Water supply to Sheerness power plant
Creek
Coleman Lake
Sheerness Plant
Creek
Carolside Reservoir
McBride Res.
Blood Indian Cr. Reservoir
S. Berry Res.
Bullpound
Cr.
Red
Deadfish
Berry
Cr.
Berry
Indian
Blood
Cr.
Hartman Reservoir
Pollockville
Nestor Reservoir
Cessford Reservoir
East
Cabin Lake
Loveland Reservoir
Deadfish Diversion
Deadfish Reservoir
Deer
River

The Study also showed where water supplies in some portions of the basins were over-allocated, and where other areas could support further development. Nearly 6000 acres (2 400 ha) of land are presently irrigated, using about 9200 dam^3 of water.

Some benefits will be provided to Berry Creek by the release of cooling water to Carolside Reservoir from a thermal generating plant at Sheerness (Chapter VIII.6), scheduled to go into operation in 1985. Alberta is spending $10 million to provide additional water for irrigation by enlarging the proposed make-up water system to the plant, and by a separate pumping scheme from the Red Deer River to Deadfish Creek Reservoir. These alternatives, plus the Sheerness blowdown water, could permit an increase of about 21,000 acres (8500 ha), which would develop most of the irrigable lands identified in the area studied.

Pettapiece and Kjearsgaard (1980) have identified fairly large tracts of irrigable land north of the Red Deer River downstream of Blood Indian Creek, but have questioned the economic feasibility of irrigating crops already grown in the area. The climate is unsuitable for the production of most specialty crops. Poor soil characteristics in the western portion, and uneven topography in the eastern portion, are other limitations cited. The authors identified 875,000 acres (350 000 ha) of the over 6 million acres (2 500 000 ha) studied in east central Alberta as being irrigable. Likely less than one-third of this lies within the Red Deer River basin.

Pedology Consultants (1980) has estimated that 1.65 million acres (670 000 ha) of developable irrigable land exists in the Red Deer River basin, of which 25 percent is in "moderate" need of water and 75 percent in "low" need of water. This report identifies these lands as being outside of irrigation districts but does not indicate the fractions which would be potentially irrigated from the Red Deer River, or from the Bow River. UMA (1981) estimated a total "commandable irrigable acreage" of 1.86 million acres in the basin.

The potential for large-scale irrigation developments in the Red Deer River basin must be considered from the perspective that Alberta is heavily committed to irrigated agriculture in the established irrigation districts in the Bow and Oldman River basins, where opportunities for expansion exist and the climate and soils are generally more suitable.

The ECA (1979c) considered it "unlikely that any major irrigation development will occur in the Red Deer River basin due to the reasonable success of dryland farming or the high capital cost of developing irrigation, or both... Alternatively, there may be areas within the Bow River basin which, because of climatic productivity, and economic advantages, should have priority over development in the Red Deer River basin."

The Dickson Dam (under construction) will not be capable of serving any large new irrigation projects that might be contemplated in the Red Deer River basin since its primary purpose is to augment late summer and winter river flows.

South Saskatchewan River Basin

Discussion of irrigation in the South Saskatchewan River basin has been subdivided according to the province in which it occurs. The Alberta portion of the basin extends from the confluence of the Bow and Oldman Rivers to the Alberta-Saskatchewan border, just east of the junction of the South Saskatchewan River with the Red Deer River.

The Ross Creek Irrigation District (RCID) (Figure 80) is the only irrigation district in the basin and is supplied from the Ross Creek basin, tributary to the South Saskatchewan River at Medicine Hat. The district was formed in 1949 by a group of local farmers and ranchers. In 1951 the PFRA constructed a 5500 dam^3 reservoir, Cavan Lake, and diversion works from Gros Ventre Creek, to provide a firmer supply for the district and also for private irrigators downstream. Most of the existing works are now in poor condition, and require extensive repair and improvement to efficiently utilize the available storage capacity. The present amount of land irrigated on a regular basis averages about 700 acres (280 ha), but because of shortages in water supply, only 350 acres (140 ha) received water in 1977.

The total area of private irrigation development in the Alberta portion of the South Saskatchewan River basin is 21,800 acres (8800 ha), and the total allocation is 31 100 dam^3 annually. Private storage capacity is 6800 dam^3. Return flows from the irrigation districts on both the Bow and Oldman Rivers contribute substantially to flow stabilization in the main stem of the river, and water supply there is seldom a problem. Two small tributary areas southwest of Medicine Hat, however, are known problem areas and are described in somewhat more detail.

Private irrigation use in the Ross Creek basin totals 6700 dam^3, with a licensed irrigated area of 4,888 acres (2000 ha). There is presently 2000 dam^3 of private storage capacity scattered throughout the upper reaches of the stream. Any significant increase in private irrigation would be contingent upon increased storage capacity or local basin transfers, and would have to be weighed against expansion of the irrigated areas in the Ross Creek Irrigation District.

Seven Persons Creek rises in the north slope of the Cypress Hills and joins Ross Creek just above the South Saskatchewan River. The privately licensed irrigated area in the basin is 6,400 acres (2600 ha), requiring an annual allocation of 7300 dam^3. There are 2900 dam^3 of privately owned storage capacity.

Lower portions of the drainage area include two storage reservoirs which form part of the downstream section of the St. Mary River Irrigation District (Figure 82). Releases can be made to improve flows in Seven Persons Creek, and return flows from irrigated areas in the SMRID also provide some benefit. However, shortages occur in the upper reaches and tributaries of Seven Persons Creek. Any increase in private irrigation upstream from Murray Lake Reservoir would probably require additional private storage capacity, and would severely tax the available water supplies of the basin.

The South Saskatchewan River drainage in *Saskatchewan* extends from the Alberta-Saskatchewan boundary to the junction of the South and North Saskatchewan Rivers near Prince Albert. The only significant tributary throughout this reach of the river is Swiftcurrent Creek.

The *South Saskatchewan River Irrigation District*(SSRID) (Figure 89) is the largest irrigation development in the basin. It was developed by Saskatchewan Agriculture and is now administered by a board of trustees. Water for this project is pumped from Lake Diefenbaker (storage capacity 9300 dam^3) to a canal along the east side of the river. Return flows drain back to the river.

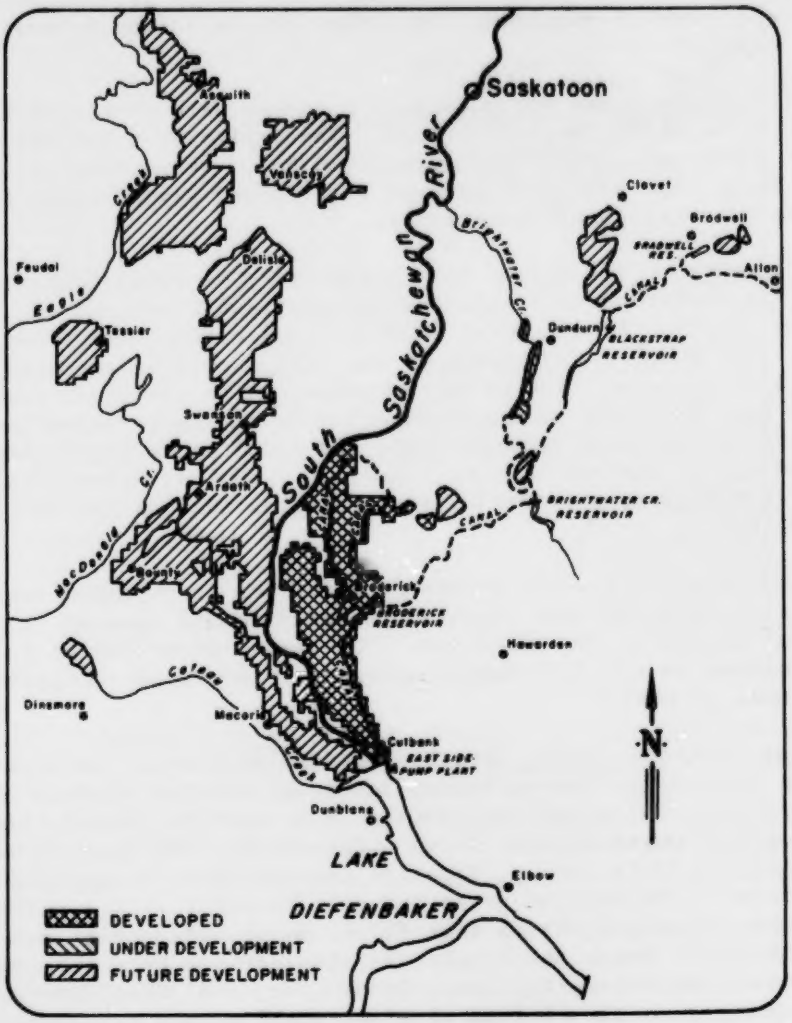
By 1980, the project had increased to a total irrigated area of 31,000 acres (12 500 ha) out of a total developed acreage of 33,100 acres (13 400 ha). The 1979 irrigation required 81 650 dam^3 of water, of which conveyance losses were 16.7 percent. Water from this canal is also supplied to the Saskatoon South-East Water Supply (SSEWS) canal system, which could service an additional 23,000 acres (9300 ha) of irrigation. In 1979, approximately 8300 acres (3300 ha) were irrigated.

Further expansion of the SSRID would soon require a pumping station on the west side of Lake Diefenbaker. About 60,000 acres (24 000 ha) is the maximum developable on the east side, but as indicated in Figure 89, nearly 200,000 acres (80 000 ha) is considered to be potentially irrigable on the west side. The project manager has suggested a foreseeable total development of 150,000 acres (60 700 ha) (SSRID, 1981). Some estimates suggest that between 40,000 and 50,000 acres (16 000 - 20 000 ha) will be irrigated by 1990.

The *Grainland Irrigation Project* just south of Qu'Appelle Dam is licensed for 1,000 acres (400 ha). The allocation is 1900 dam^3 (from Lake Diefenbaker). In 1981 the project was expanded to approximately 2,500 acres (1000 ha) and is now fully developed.

The *Miry Creek Water Users District* is situated on crown land adjacent to the South Saskatchewan River upstream of Lake Diefenbaker. It was formed in 1969 and was fully developed by 1977. The area under irrigation is about 1,600 acres (660 ha), and an allocation of 3500 dam^3 has been assigned. The *Chesterfield Water Users District* also obtains water from the South Saskatchewan River (near the Alberta border) and is licensed for about 700 acres (300 ha).

Figure 89. THE SOUTH SASKATCHEWAN RIVER IRRIGATION DISTRICT (SSRID) (WER, 1980b).


Saskatoon
South Saskatchewan River
Asquith
Vanscoy
Creek
Clavet
Bradwell
BRADWELL RES.
Allan
CANAL
Feudal
Eagle
Delisle
Brightwater Cr.
Tessier
Dundurn
BLACKSTRAP RESERVOIR
Swanson
Ardath
Cr.
BRIGHTWATER CR. RESERVOIR
CANAL
MacDonald
Bounty
Broderick
BRODERICK RESERVOIR
Hawarden
Coteau
Creek
Dinsmore
Macorie
Culbank
EAST SIDE PUMP PLANT
N
Dunblane
LAKE DIEFENBAKER
Elbow
DEVELOPED
UNDER DEVELOPMENT
FUTURE DEVELOPMENT

Duncairn Reservoir (Reid Lake) (storage capacity - 104 000 dam^3) on Swiftcurrent Creek was constructed by PFRA in the early 1940s to provide a firm supply for the Swiftcurrent Project and the North Waldeck and Herbert Projects (Figure 90), via an irrigation supply canal and the Highfield Reservoir.

The Swift Current Project was developed by the PFRA near the village of Rush Lake in what was formerly a lake bed. The total irrigated area is 5,900 acres (2400 ha), which is considered to be the probable maximum limit that can be served by available water supplies.

The Herbert and North Waldeck Projects were developed by the Province as Water Users Districts. The irrigable areas are 1,400 acres (560 ha), and 1,650 acres (670 ha), respectively. It is not likely that irrigated acreage will expand beyond these totals because of water supply constraints.

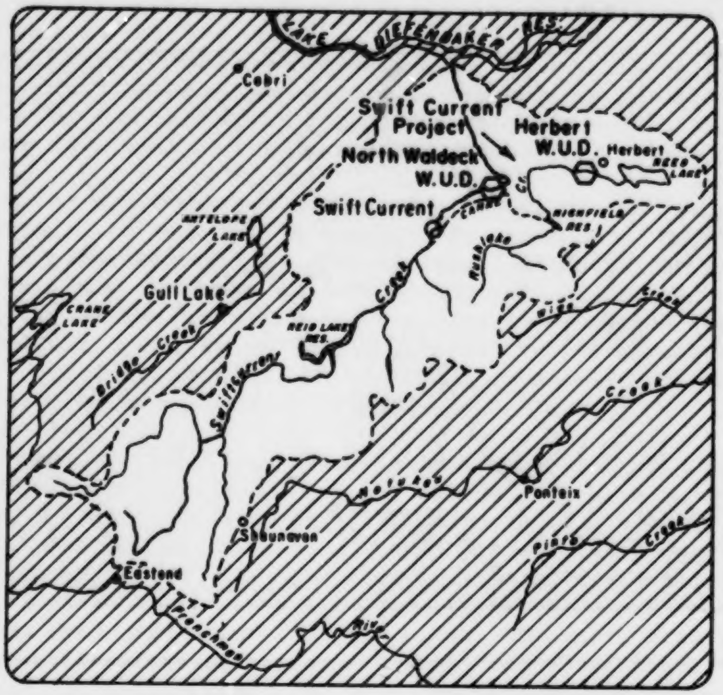
Private irrigation developed from the South Saskatchewan River in Saskatchewan (excluding Swiftcurrent Creek and the SSEWS canal) totals 20,600 acres (8300 ha), with an annual allocation of 32 000 dam^3. Expansion of the irrigated area supplied from the main stem of the river is expected to continue, although there has been no assessment of the ultimate potential for private irrigation. Between 3,000 and 4,000 acres (1200-1600 ha) are being added each year, however, and discussions with officials suggest a possible increase to as much as 100,000 acres (40 000 ha).

Private irrigation in the Swiftcurrent Creek basin began in the late 1890s and has expanded steadily to its present licensed area of 8,600 acres (3500 ha). The demand allocated to private irrigation is 10 400 dam^3 annually. Only minor expansion in some areas is possible.

The Cypress Hills North Slope drainage area consists of a number of small closed basins involving streams originating in the Cypress Hills and terminating in evaporation lakes south of the South Saskatchewan River (Figure 91). Of the six basins included in this group, Bigstick Lake and Many Island Lake are considered to be problem areas and will be dealt with separately. Antelope Lake basin has a significant municipal project near the town of Gull Lake, but further development has been restricted. The remaining three, Hay Lake, Crane Lake, and Skull Creek, are important sources of feed supplies locally, but do not contain any community projects or large storage reservoirs.

The total area irrigated, including Bigstick and Many Island Lakes, is 29,800 acres (11 600 ha), requiring a licensed allocation of 41 900 dam^3. Modest increases in irrigated areas in the Hay Lake, Crane Lake, Skull Creek and Antelope Lake basins are expected, but would probably necessitate construction of additional storage capacity.

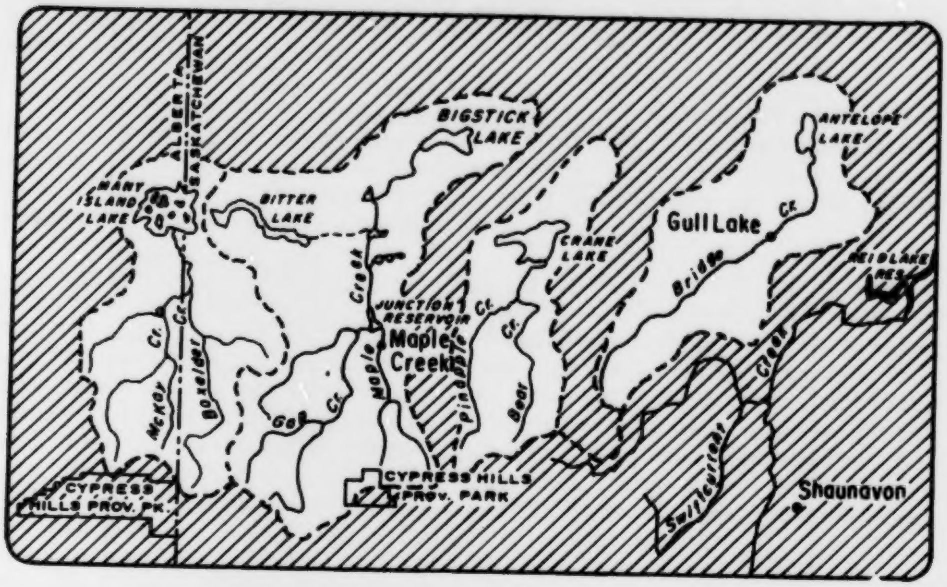
Figure 90. SWIFTCURRENT CREEK IRRIGATION PROJECTS (WER, 1980b).


LAKE DIEFENBAKER RES.
Cabri
Swift Current Project
Herbert W.U.D.
Herbert
REED LAKE
North Waldeck W.U.D.
Swift Current
CANAL
Cr.
HIGHFIELD RES.
ANTELOPE LAKE
Rushlake
Gull Lake
CRANE LAKE
Bridge Creek
REID LAKE RES.
Swiftcurrent Creek
Creek
Creek
Notukeu
Ponteix
Shaunavon
Pinto Creek
Eastend
Frenchman
River

The Bigstick Lake basin (Figure 91) has been extensively developed. In 1939, PFRA constructed three reservoirs on Maple and Gap Creeks, and added a fourth in 1956 for a total storage capacity of 30 200 dam^3. In the 1940s it developed an irrigation project on the Maple Creek flats and the Vee Projects, some 32 kilometres to the north.

The area presently irrigated on the Maple Creek Flats is 2,650 acres (1070 ha), with a further 1,100 acres (450 ha) on the upper and lower Vee. The projects are authorized by the Saskatchewan Water Rights Branch but have not been assigned any specific allocations. PFRA regards them as fully developed based on available water supplies, and no further expansion is envisioned. A study conducted by Saskatchewan Environment (1977b) confirmed that no further development is indicated, and that some reduction in private use in tributary areas would be desirable. The private irrigation licensed in the basin is 6,500 acres (2600 ha) with a total annual allocation of 9500 dam^3.

Figure 91. CYPRESS HILLS NORTH SLOPE DRAINAGE BASINS (WER, 1980b).


ALBERTA
SASKATCHEWAN
MANY ISLAND LAKE
BITTER LAKE
BIGSTICK LAKE
ANTELOPE LAKE
Gull Lake
Cr.
CRANE LAKE
Bridge
REIDLAKE RES.
Creek
JUNCTION RESERVOIR
Maple Creek
Cr.
Cr.
Cr.
McKoy
Boxelder
Cr.
Gap
Cr.
Maple
Piapot
Cr.
Bear
Creek
Swiftcurrent
Shaunavon
CYPRESS HILLS PROV. PARK
CYPRESS HILLS PROV. PK.

The Many Island Lake basin terminates in Many Island Lake, located astride the Alberta-Saskatchewan border (Figure 91). The available water resources are heavily developed, with 6000 acres (2400 ha) of irrigation in Alberta requiring a licensed allocation of 9200 dam^3, and 2,600 acres (1000 ha) under private license in Saskatchewan requiring an annual allocation of 2600 dam^3. Shortages of water are frequent, and large expenditures for additional storage are not warranted given the unreliable runoff. Further irrigation expansion is unlikely. Studies of possible reservoir sites were conducted by PFRA some years ago, but none has been constructed. Alberta Environment is concerned about water supply problems in this basin and is considering a detailed study of water supply and management.

North Saskatchewan River Basin

Because of the lower heat units and generally higher average precipitation in the North Saskatchewan River basin compared to more southerly basins, private irrigation developed there at a later period and is not as extensive. In Alberta, 3,300 acres (1300 ha) of private irrigation are amply supplied from the river itself, the allocation being 3800 dam^3.

Of the total irrigated acreage in the basin, 9,600 acres (3900 ha) are within the Battle River basin, requiring an annual allocation of 10 300 dam^3. There are 6100 dam^3 of privately owned storage. While no restrictions have yet been placed on further development, the supply is regarded as borderline, and the Alberta Water Rights Branch now recommends that additional storage be developed to supply any new private irrigation.

Another tributary, the Sturgeon River, has not experienced any shortages to date but is regarded by the Alberta Water Rights Branch as being a potential problem area. Although the principal crop along the Sturgeon is devoted to feed and forage, a number of large commercial sod farms are also in operation. The area used for the growing of sod is expected to increase because of proximity to Edmonton. At present, about 1700 acres are irrigated, with an allocation of 1400 dam^3.

Irrigation in the Saskatchewan portion of the North Saskatchewan River basin is not extensively developed. Water rights files indicate a total irrigated area of 7,400 acres (3000 ha), requiring an annual allocation of 9100 dam^3. The Northminster Water Users District is being developed north of Lloydminster and will use water from the North Saskatchewan River and municipal effluent from the city. The water supply in the main stem is adequate to support significant increases in these figures, but Eagle Creek, the major tributary from the south, is an intermittent stream and can support only a small increase in development. However, much of the land in this basin could be irrigated as a part of the west side of the SSRIP.

The Manito Lake closed drainage area, which includes Sullivan, Kiyiu, and Dead Lakes drainage basins, is generally very dry, extending from central Alberta to west central Saskatchewan. The area licensed for irrigation in Alberta totals about 2,000 acres (800 ha), with a licensed allocation of 2100 dam^3. No new projects have been licensed since 1977 because of uncertain water supply, and the presently irrigated acreage is not expected to increase significantly. Phase II of an Alberta Environment study of water supply, management, and use in the Special Areas, which deals with the Sounding Creek basin, is now nearing completion.

There is very little irrigation in the Saskatchewan portion of this basin, but some of the land would eventually be irrigated as a part of the SSRIP.

Saskatchewan River Basin

The Saskatchewan River Basin extends from the confluence of the North and South Saskatchewan Rivers to Lake Winnipeg. Irrigation development is minimal, but interest is growing. The total irrigated area is 318 acres (129 ha), and the allocation for irrigation use is 300 dam^3.

Qu'Appelle River Basin

The Qu'Appelle River originates near the Qu'Appelle Dam on Lake Diefenbaker and flows eastward across Saskatchewan into Manitoba where it joins the Assiniboine River. The Saskatchewan Nelson Basin Board Report (1972) indicated that about 20,000 acres (8100 ha) of land in this basin are under private irrigation in the floodplain. However, Saskatchewan Water Rights Branch files indicate a licensed area of only 10,100 acres (4100 ha) with an annual demand of 9800 dam^3. The discrepancy can probably be attributed to the fact that large areas of valley bottom flood in most years, and it is assumed that some of these areas are not licensed but were considered irrigated by the SNBB. As well, many farmers have carried out unauthorized spring flood irrigation by construction of temporary earth dams.

One small Water Users District (Avonlea - 270 acres) has been developed by the province, and a second (Baildon) is being formed south of Moose Jaw. The latter will irrigate using sewage effluent from Moose Jaw and is being planned for 1000 acres (400 ha) initially.

Saskatchewan Agriculture (WER, 1980) estimates the total potential area of intensive irrigation in the Qu'Appelle basin at 64,000 acres (26 000 ha), with an additional 24,000 acres (9700 ha) which could be irrigated once a year. However, such development would require that more water be diverted from Lake Diefenbaker. Modest expansion is expected as channel improvements are made.

The Quill Lakes closed drainage area, included with the Qu'Appelle River basin, has less than 200 acres (80 ha) of irrigation.

Assiniboine River Basin

The Assiniboine River basin includes the Souris River basin, but the latter is discussed separately below.

The Souris River rises in southeastern Saskatchewan, flows southeasterly into North Dakota, then recrosses into Manitoba where it joins the Assiniboine River. Interim apportionment presently in effect provides that Saskatchewan must release to North Dakota one-half of the natural flow originating in Saskatchewan and maintain a minimum flow at the boundary of 0.1 m^3/s. Weyburn Reservoir on the Souris and Boundary Dam on Long Creek store most of the flow in many years from these streams for municipal use and to supply cooling water for a large thermal generating plant (Chapter VIII.6). These factors permit only limited irrigation development from the Souris in Saskatchewan, ammounting to 3,500 acres (1400 ha), plus a small Water Users District at Dead Lake Reservoir (150 acres). The total allocation is 3600 dam^3, and about 70 percent of the irrigation water is drawn from the main stem. Available water supplies probably will not permit a very significant increase in these figures.

Saskatchewan Agriculture has estimated that there is a potential for irrigating 8,000 acres (3200 ha) in the Souris River Valley in Saskatchewan, and an additional 60,000 acres (24 000 ha) on the uplands (SRBSB, 1978). Of this potential, it has projected that only 6,000 acres (2400 ha) within the valley will be irrigated in the long-term future, and that none of the 60,000 acres of upland area would be developed, even if irrigation water were made available. The SRBSB estimated that a total of 47,000 acres (19 000 ha) would be irrigated in the long-term future with importation, but they found that it would only be economical to import water if industrial demands increased substantially. Under the 1979 Canada-Saskatchewan water development agreement (Chapter I.7), water supply developments, including a new Weyburn Dam, will be constructed, partly for agricultural purposes.

Water rights records for the Manitoba portion indicate a total allocation for irrigation of 2000 dam^3 from the Souris River, with an additional 600 dam^3 from tributary streams. In making its estimates of annual water requirements for future irrigation, the SRBSB assumed the following irrigated acreages:

- 2,000 acres (800 ha) in the foreseeable future,

- 12,000 acres (5000 ha) in the long-term future without importation,

- 100,000 acres in the long-term future with importation.

Irrigation development along the Assiniboine River has been very limited to date, mainly because of variable water supplies in some areas and climatic conditions which are quite favorable to the growth of crops without irrigation. The total licensed irrigation is only 455 acres (185 ha), requiring an annual demand of 480 dam^3. Some farmers have expressed an interest in developing more land for irrigation, but increases are not likely to be large.

In Manitoba, the Assiniboine River includes the largest amount of irrigation of any of the drainage areas in that province. Manitoba water rights records do not designate the actual areas irrigated, but the total licensed allocation from this basin (including tributaries) for irrigation purposes is 11 800 dam^3. The Garrison Diversion Study Board listed only 1,550 acres (627 ha) irrigated from surface waters in 1975 (International Garrison Study Board, 1976) with 2500 dam^3 actually used. Some irrigation from ground water exists near Brandon, and the province is presently refining its approach to licensing ground water for this purpose. Aquifers near Carberry and Oak Lake are of particular interest.

The Shellmouth Reservoir, with a storage capacity of 477 000 dam^3, and the Rivers Reservoir on the Little Saskatchewan River provide a firm supply for those projects located downstream, and irrigated acreages are expected to increase substantially over the presently licensed quantities. The Manitoba Department of Agriculture has predicted an irrigated area of 45,000 acres (18 000 ha) in the Assiniboine basin by the year 2000 (WER, 1980).

A recent Canada-Manitoba (1980) agreement has resulted in studies on water demand and possibilities for enhancing supply to the region generally between Portage la Prairie and Winnipeg, and south almost to the United States border. This is called the Assiniboine-South Hespeler region, also termed the "Pembina Triangle". Options being explored are:

- diversion from the Assiniboine to the LaSalle River,
- storage on the Assiniboine, including construction of a dam (Holland Dam) to facilitate supply by canal southward,
- importation of water from Lake Manitoba to the Assiniboine, then southward by canal, and
- importation of water from Lake Diefenbaker, either through the Qu'Appelle River, or via diversion to the Souris River.

In each case, irrigation would benefit. Details of works necessary are found in SNBB (1972). Return flow drainage via the LaSalle River and other streams would be to the Red River. It is estimated that about 1 million acres in this region are suitable for irrigation, though that figure would not likely ever be reached.

Red River/Lake Winnipeg Basin

The Red River rises in the United States and flows northward, joining the Assiniboine River in Winnipeg, then continuing northward to Lake Winnipeg. The total annual quantity of water from the main stem of the river allocated for irrigation use is only 540 dam^3. Studies by the International Garrison Diversion Study Board indicated approximately 800 acres (325 ha) irrigated in 1975, 400 acres (160 ha) of which were supplied by groundwater pumping. Projections prepared by that Board indicated that irrigation use would increase to 1900 dam^3 by the year 2000, a figure which would appear rather optimistic in view of the growth rate to date, although additional land could be developed with diversion from the Assiniboine River. Lands adjacent to the river on the west side are not considered to be suitable for irrigation due to the type of soil found there.

The Pembina River originates in Manitoba and crosses into North Dakota, where it joins the Red River just south of the border. The present licensed irrigation demand in Manitoba totals 1600 dam^3, and the feasibility of significant expansion of irrigation in the Pembina beyond that figure is not known.

The Lake Winnipeg basin area, which includes the Winnipeg, Brokenhead, and Whitemouth Rivers, has very little irrigation development to date.

The Lake Dauphin basin includes the Turtle, Ochre, Vermillion, Wilson and Valley Rivers. Irrigation development is quite limited, with a total allocation of 860 dam^3. No information is available regarding possible expansion of this figure.

The Lake Manitoba basin includes irrigation use along the Whitemud River, Pine Creek, and the Portage Diversion. The total allocation according to water rights records is 3700 dam^3, with an additional 700 dam^3 on smaller tributaries. The Garrison Study Board suggested that large areas of highly productive irrigable soils located north and east of Portage la Prairie could be developed, but they do not consider such development from Lake Manitoba streams to be very likely (WER, 1980b).

There are also several small unnamed streams and some small drainage basins tributary to lakes which seldom, if ever, overflow. The total licensed irrigation demand in these is 1300 dam^3, and the ability of existing supply sources to support further development is not known.

Churchill River Basin

The area of the Churchill River basin in Alberta is relatively small, and because of its northern location, irrigation is not an important factor. The total licensed demand is only 380 dam^3, which supplies 334 acres (135 ha) of irrigation. The storage capacity is 380 dam^3. Similarly, there is very little irrigation in Saskatchewan and none in Manitoba, though the Churchill River is one of the largest rivers in these provinces.

Missouri River Drainage

The Milk River is an international stream which originates in Montana, flows through Alberta for some 240 kilometres, and re-enters Montana where it eventually joins the Missouri River. Canada's share of its waters is controlled by the Boundary Waters Treaty of 1909 and the Apportionment Agreement of 1921. In essence, the latter permits Canada to divert somewhat less than half the natural flow of the Milk River in exchange for slightly more than half the natural flow of the St. Mary River. Furthermore, the United States diverts its store of the St. Mary River to the Milk River for transfer through Canada to the lower reaches in Montana.

The basin is located in an extremely dry area, and private irrigation development began shortly after the area was settled in the late 1800s. The total licensed private irrigation in the Milk River basin, including several of the tributaries which originate in Alberta and join the Milk River in Montana, is 8,200 acres (3300 ha) with an allocation of 12 800 dam^3. There is private storage capacity of 13 200 dam^3, but most of it is concentrated in three tributary headwaters reservoirs which seldom fill.

Irrigators in Canada have experienced water shortages on many occasions, in spite of the fact that historically the average flow to the United States has exceeded international commitments by some 48 000 dam^3 per year (DREE, 1978). This is largely due to the fact that only 25 percent of irrigation withdrawal is from the main stem, the balance being from the tributaries. Further development, although not restricted, has been discouraged by the Alberta Water Rights Branch because of the inadequate and uncertain supply.

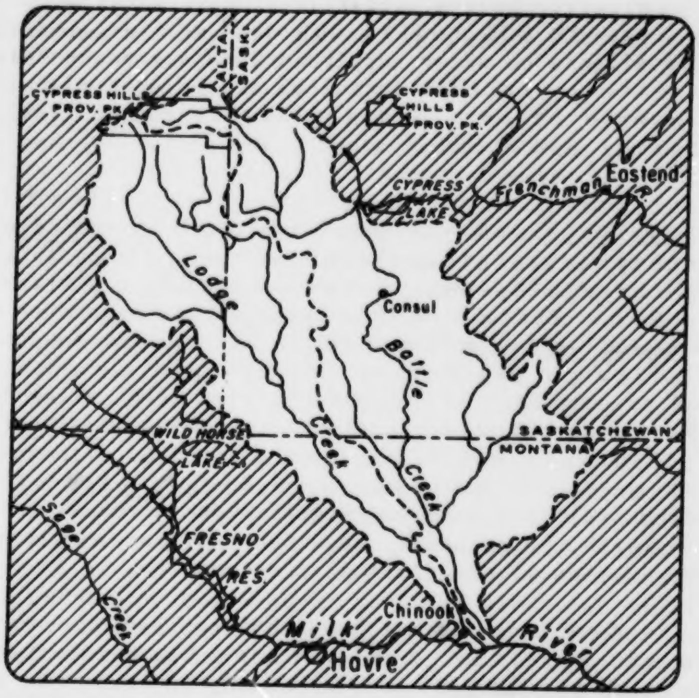
Studies by PFRA and Alberta Environment to determine the feasibility of developing major storage works on the Milk River are in progress. Five alternative storage sites with capacities ranging from 28 000 to 123 000 dam^3 were examined initially, and their effects on water supply in Canada and the United States were assessed. Further technical and related planning studies which examine other storage alternatives and environmental, sociological and economic aspects are partially completed (WER, 1980b).

Lodge Creek and its principal tributary Middle Creek are both interprovincial and international, rising in Alberta and flowing through Saskatchewan and down to the Missouri system (Figure 92). There are two separate constraints on use of its waters in Alberta, since Canada is required to pass half the natural flow to the United States, and Alberta is legally entitled to only half of the natural flow originating in Alberta. This has restricted irrigation development in Alberta to 3,800 acres (1530 ha), which requires a licensed allocation of 5100 dam^3. There are 2300 dam^3 of storage, most of which is located on small tributaries. Significant increases in irrigation in this part of the Lodge Creek sub-basin are not considered to be likely in view of the limited water supplies.

Lodge Creek in Saskatchewan has two large reservoirs, both constructed by PFRA. Middle Creek Reservoir has a storage capacity of 16 300 dam^3 and, depending on reservoir levels, can release water to either Lodge or Middle Creeks. Altawan Reservoir, located on Lodge Creek, has a live storage capacity of 7000 dam^3. As noted earlier, Saskatchewan is only guaranteed half of the natural flow which originates in Alberta, and half the natural flow originating in Canada must be released to the United States. Two irrigation projects have been developed by Saskatchewan as Water Users Districts.

The Spangler Project was originally a privately-owned scheme which is now operated as part of the Lodge Creek Water Users District. It is located immediately downstream of Altawan Reservoir and in most years water supplies are adequate for at least one application. The total developed irrigated area is 1000 acres (400 ha), and no expansion of this figure is planned. The project has been extensively levelled and was developed with a border dyke system of irrigation to provide feed supplies for the predominantly ranching area adjacent to the project.

Figure 92. LODGE CREEK AND BATTLE CREEK DRAINAGE BASINS (WER, 1980b).


ALTA
SASK
CYPRESS HILLS PROV. PK.
CYPRESS HILLS PROV. PK.
CYPRESS LAKE
Frenchman
Eastend
Consul
Lodge Creek
Battle Creek
SASKATCHEWAN
MONTANA
WILD HORSE LAKE
FRESNO RES.
Sage Creek
Chinook
Milk River
Havre

The Middle Creek Project was developed with assistance from the province near Govenlock, and is supplied by releases from Middle Creek Reservoir. The area presently irrigated is 1100 acres (440 ha), which is still operated under provincial jurisdiction as a water users district.

Private irrigation from Lodge Creek and its tributaries in Saskatchewan has developed to a total of 7,100 acres (2900 ha), with an annual water allocation of 7100 dam^3. Private irrigation reservoirs contain an aggregate storage of 3200 dam^3, in addition to Altawan and Middle Creek Reservoirs which provide controlled releases for private irrigation.

The basin is considered to be approaching its maximum level of development based on available water supplies. Water supplies are short, and frequently the shortages are critical.

Battle Creek, also shown in Figure 92, rises in the Cypress Hills near the Alberta-Saskatchewan boundary and flows southeasterly through Saskatchewan to Montana where it joins the Milk River. Like Lodge Creek, it is subject to the provisions of the 1921 Apportionment Order which states that half the natural flow at the boundary must be passed to the United States.

Cypress Lake Reservoir, with a total storage capacity of 128 000 dam^3, is located between Battle Creek and the headwaters of the Frenchman, and existing diversion works permit water to be diverted from both streams for storage in Cypress Lake. Releases can be made to either the Frenchman River or Battle Creek as required.

Because of its location in a typical ranching area, private irrigation developed at an early stage in the history of the region. Three large privately-owned projects (Richardson, Nashlyn, and McKinnon) were taken over by PFRA in the early 1940s and are now operated as the Consul Project.

The Consul Project is supplied by two diversion weirs on Battle Creek, and relies on Cypress Lake as its only storage reservoir. The acreage on the original projects has been enlarged to a total area of 3,450 acres (1400 ha), almost all of which is irrigated by means of a border dyke system.

Another development, the Vidora Project, is supplied directly by canal with water released from Cypress Lake, and has a small internal balancing reservoir. It was developed by Saskatchewan and is operated by a local Water Users Association. Its total irrigated area of 2,400 acres (1000 ha) is not expected to expand unless more water can be made available from Cypress Lake.

Private irrigation use in the Battle Creek basin in Saskatchewan totals 7,100 acres (2850 ha), with a total annual licensed allocation of 7100 dam^3. Any significant increase in private irrigation would again depend on increased releases from Cypress Lake, and would have to be weighed against alternative increases in the Consul or Vidora projects.

With the low runoff years experienced through the late 1970s, carry-over supplies in Cypress Lake have been seriously depleted, and irrigation use on the projects has been restricted. Recent studies by PFRA (1976) of water supply and management in the Frenchman River basin indicated that if a large reservoir were developed on the Frenchman, an additional 2500 dam^3 from Cypress Lake would be available annually for use in the Battle Creek basin.

The Frenchman River originates on the south slopes of the Cypress Hills and flows southeastward through Saskatchewan for approximately 160 kilometres, then crosses into Montana and eventually into the Missouri River system (Figure 93). It is an international stream and, as such, the apportionment of its flows are also subject to the provisions of the 1909 Boundary Waters Treaty and the 1921 Apportionment Order which stipulates that half of the natural flow of the Frenchman River at the international boundary must be passed to the United States.

Private irrigation supplied from the river and its tributaries began shortly after the area was first settled. The larger community projects, Eastend, Val Marie, and West Val Marie, were not developed until shortly after the formation of the PFRA in 1935. Reservoirs were constructed by PFRA at each of the three projects and the natural storage at Cypress Lake in the Frenchman River headwaters was increased to 128 000 dam^3 by the construction of dams and diversion works.

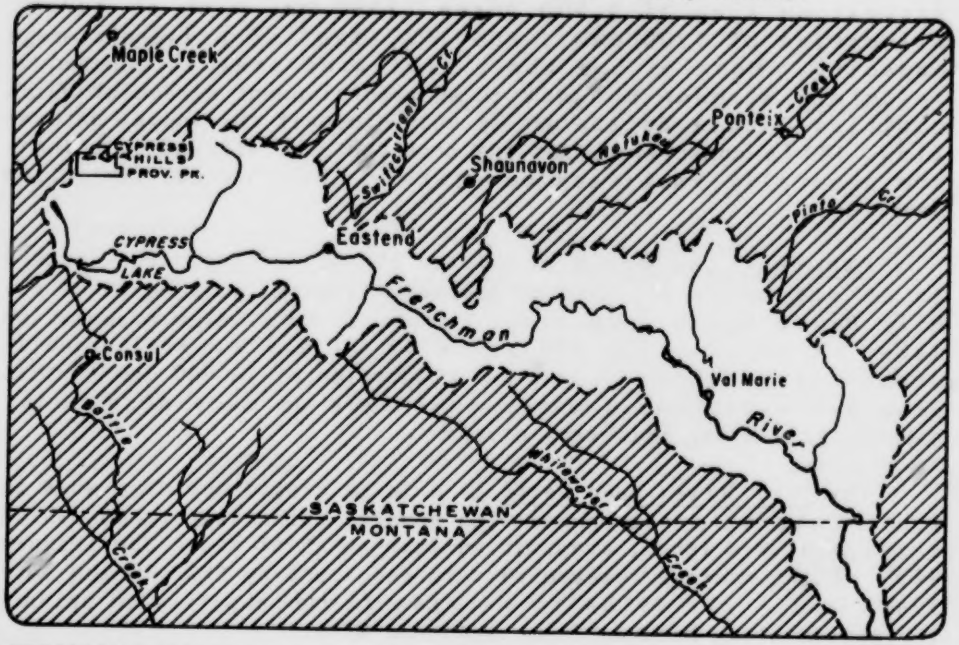
The Eastend Project was initiated about 1939, with the construction of a 2500 dam^3 onstream reservoir and a project distribution system. The method of irrigating is mainly by border dykes, which has required an extensive program of land levelling. The project has gradually been expanded and improved to its present level of 2,900 acres (1200 ha) of irrigation. No significant expansion from this figure is foreseen unless additional reservoir storage capacity is provided.

The Val Marie Project was developed about the same time as Eastend. The storage capacity of the Val Marie Reservoir is 11 500 dam^3, and the area presently under irrigation within the project is 4,300 acres (1750 ha). The reservoir also provides water for use by private irrigators downstream along the river. As in the case of the Eastend Project, its area will not expand significantly with the present water supply.

The West Val Marie Project requires pumping from its reservoir to the main canal gravity system. The reservoir capacity is 4200 dam^3 and the total irrigated area is 2,800 acres (1100 ha). Under present storage conditions, expansion is not expected.

Private irrigation in the Frenchman River basin is extensively developed, with a total of 8,700 acres (3500 ha) under irrigation. The allocation, according to the Saskatchewan Water Rights Branch, is 10 100 dam^3, and a total private storage reservoir capacity of 1400 dam^3 has been developed. Shortages of water have occurred in tributary areas and along the main stem of the river on many occasions, and large increases in irrigated

Figure 93. FRENCHMAN RIVER DRAINAGE BASIN (WER, 1980b).


Maple Creek
Cr.
Ponteix
Creek
Notukeu
Shaunavon
CYPRESS HILLS PROV. PK.
Swiftcurrent
Pinto Cr.
Eastend
CYPRESS LAKE
Frenchman
Consul
Val Marie
River
Battle
Whitewater
SASKATCHEWAN
MONTANA
Creek
Creek

acreage would not be possible unless additional storage were provided. However, to date, restrictions have not been placed on further private development, so some increase is expected. If additional storage capacity were constructed, priorities between private irrigation expansion and enlargement of the irrigation projects would have to be established.

The feasibility of developing additional storage capacity was examined by the PFRA (1976) which found that a 125 000 dam^3 reservoir at one of the sites studied would satisfy almost the entire present irrigation demand on the Frenchman River (24 000 dam^3), free 2500 dam^3 of Cypress Lake water for other uses, and also provide an additional 2700 dam^3 for new development. It would also reduce excess flows to the USA considerably. However, the reservoir site is expensive, and a cost-benefit analysis indicated costs to be far in excess of the benefits.

A total of 16 additional small basins located on streams tributary to the Milk or Missouri Rivers are situated along the international boundary. Generally, the areas involved are not extensive and irrigation development is limited because of uncertain water supplies. They involve an aggregate licensed irrigation area of 5,400 acres (2200 ha) with an annual allocation of 4200 dam^3, and 1400 dam^3 of private storage capacity. Most of the above irrigated area is located on tributary streams subject to an apportionment agreement which entitles Canada to the use of only one-half the annual natural flow. This constraint, and the fact that the streamflow volumes are generally small and unreliable, has limited irrigation development.

Pakowki Lake basin is a large closed drainage area located in an extremely dry part of southern Alberta, just north of the Milk River basin. Drainage terminates in a large evaporation lake. A total of 13,600 acres (5500 ha) of irrigation is presently licensed, with an allocation of 14 400 dam^3. This area has experienced water shortages on many occasions, particularly along tributary streams.

The Old Wives Lake basin is a large closed drainage area in south-central Saskatchewan with several tributary streams which terminate in a large, evaporation lake south of Moose Jaw (Figure 94). Eight storage reservoirs were developed by PFRA in the late 1940s and early 1950s to provide firmer supplies to private irrigation along Notukeu Creek and Wood River.

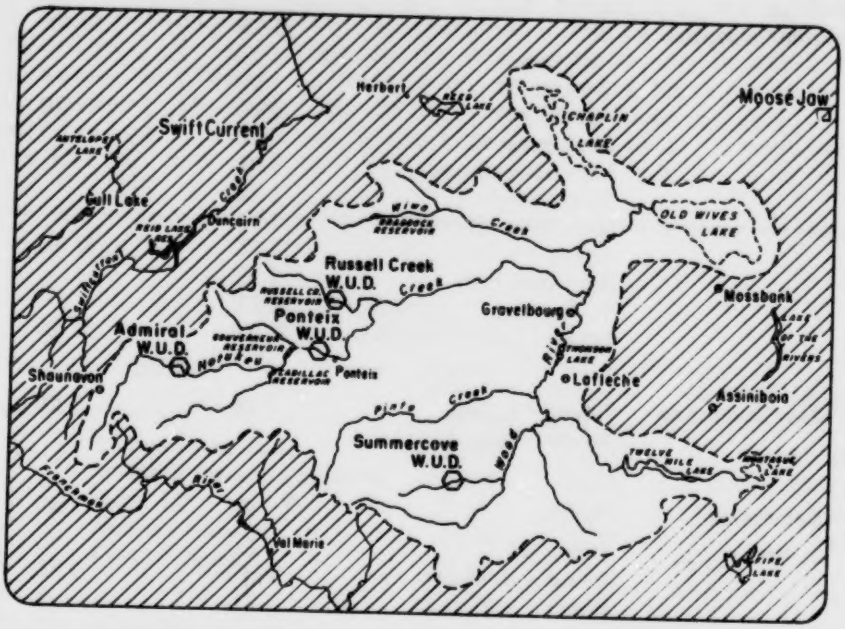
More recently, four projects which are also supplied from those reservoirs have been organized by Saskatchewan Agriculture. The area developed in these projects totals 2,800 acres (1100 ha), of which 1,800 acres (700 ha) were irrigated in 1978.

Private irrigation in the basin has steadily increased to its present level of 14,200 acres (5750 ha) with an allocation of 12 800 dam^3. The aggregate private storage capacity is 3500 dam^3. New development is possible in some areas, but water is generally in short supply.

Athabasca River Basin

The total licensed irrigation demand in the Athabasca River basin is 2300 dam^3 with 1,750 acres (710 ha) irrigated, mostly in the Paddle and Pembina River basins. Storage capacity is 4100 dam^3 which provides a fairly reliable supply. Irrigated acreage is not expected to increase significantly in the near future.

Figure 94. OLD WIVES LAKE BASIN IRRIGATION PROJECTS (WER, 1980b)


Herbert
Reed Lake
Chaplin Lake
Moose Jaw
Swift Current
Antelope Lake
Gull Lake
Creek
Duncairn
Reid Lake Res.
Wiwa
Braddock Reservoir
Creek
Old Wives Lake
Russell Creek W.U.D.
Russell Cr. Reservoir
Creek
Ponteix W.U.D.
Gravelbourg
Mossbank
Lake of the Rivers
Swiftcurrent
Admiral W.U.D.
Gouverneur Reservoir
Notukeu
Cadillac Reservoir
Ponteix
Thomson Lake
River
Lafleche
Shaunavon
Pinto Creek
Assiniboia
Summercove W.U.D.
Wood
Twelve Mile Lake
Montague Lake
Frenchman
River
Val Marie
Fife Lake

Peace River Basin

Irrigation in the Peace River basin is also very limited. In Alberta there is a total licensed demand of only 880 dam^3 with 680 acres (275 ha) irrigated. In British Columbia there are only 15 irrigation licenses involving an area of 1,585 acres (640 ha). License applications for a further 800 acres have been received and are being processed. The actual amount of water used varies widely from year to year depending on the amount of precipitation during the growing season.

Provincial Overviews

Although the fraction of cropland committed to irrigation in the drainage region is very small (six percent in Alberta and less than one percent in Saskatchewan and Manitoba), yields are generally much higher than from dryland farming. The agricultural value difference depends on soil type, moisture deficit, suitability of land for irrigation, and distance of the land from population centres (UMA, 1981).

TABLE 65. IRRIGATION IN SASKATCHEWAN

BASIN	PROJECT	ACRES DEVELOPED		DAM^3 ALLOCATED
SOUTH SASKATCHEWAN	SSRIP	33 100		81 600
	SSEWS CANAL	8 300		
	GRAINLAND WUD	2 500		
	MIRY CREEK WUD	1 600		3 500
	CHESTERFIELD WUD	700		
	SWIFT CURRENT PROJECT	5 900		
	HERBERT PROJECT	1 400		
	NORTH WALDECK PROJECT	1 600		
	PRIVATE - S. SASK.	29 200		42 400
	MAPLE CREEK FLATS	2 700		
	VEE PROJECTS	1 100		
	PRIVATE - CYPRESS HILLS N.S.	20 000		32 700
	TOTAL:		108 100	
NORTH SASKATCHEWAN	PRIVATE - N. SASK.	7 400		9 100
	PRIVATE - MANITO L.	?		
	TOTAL:		7 400+	
SASKATCHEWAN	PRIVATE	300		300
QU'APPELLE	AVONLEA WUD	250		
	PRIVATE - QU'APPELLE	10 000+		9 800
	PRIVATE - QUILL LAKES	200		
	TOTAL:		10 500+	
ASSINIBOINE	DEAD LAKE WUD	150		
	PRIVATE - SOURIS	3 500		3 600
	PRIVATE - ASSINIBOINE	500		500
	TOTAL:		4 150	
MISSOURI	SPANGLER PROJECT	1 000		
	MIDDLE CREEK WUD	1 100		
	PRIVATE - LODGE CR.	7 100		7 100
	CONSUL PROJECT	3 400		
	VIDORA PROJECT	2 400		
	PRIVATE - BATTLE CR.	7 100		7 100
	EASTEND/VAL MARIE PROJECTS	10 000		
	PRIVATE - FRENCHMAN	8 700		10 100
	PRIVATE - MISC.	5 400		4 200
	OLD WIVES L. WUD	2 800		1 800
	PRIVATE - OLD WIVES L.	14 200		12 800
	TOTAL:		63 200	
ALL BASINS	TOTAL:		193 650+	

TOTAL AREA UNDER CROPS - 26 200 00 ACRES (1976)

WUD - WATER USERS DISTRICT

Concern about the general state of the agriculture industry, and expectations of future growth in the demand for its products, will undoubtedly sustain or increase a desire for expansion of irrigation. From the preceeding descriptions, it is clear that many areas suffer water shortages, especially in dry years, and that present irrigation systems are inadequate in some areas. Summaries of provincial irrigation statistics are contained in Tables 65, 66, and 67.

Table 66. IRRIGATION IN ALBERTA

BASIN	PROJECT	ACRES DEVELOPED	ACRES IRRIGATED -1979	DAM^3 ALLOCATED	DAM^3 CONSUMED -1979
Oldman	St. Mary Project	399 500	350 400		477 800
	Lethbridge Northern I.D.	111 900	115 800		154 500
	United I.D.	33 500	32 800		9 700
	Foothills districts	11 300	11 200		6 400
	Private - Oldman	50 000		89 900	
	Total:	606 200			
Bow	Western I.D.	74 500	46 600		122 100
	Eastern I.D.	227 300	213 800		499 100
	Bow River I.D.	150 200	133 500		218 300
	Private - Bow	30 000		43 000	
	Total:	482 000			
Red Deer	Private	32 600		44 700	
South Saskatchewan	Ross Creek I.D.	700			
	Private - S. Sask.	21 800		31 100	
	Private - Many Is. L.	6 000		9 200	
	Total:	28 500			
North Saskatchewan	Private - N. Sask.	14 600		15 500	
	Private - Manito L.	2 000		2 100	
	Total:	16 600			
Missouri	Private - Milk	8 200		12 800	
	Private - Lodge Cr.	3 800		5 100	
	Private - Pakowki	13 600		14 400	
	Total:	25 600			
All Basins	Total:	1 191 500			

Total area under crops (1976) 18 800 000 acres

Options for enhancement of irrigation capabilities vary from place to place. Major works for storage and diversion which could play important roles in this regard have, for the most part, been described by the SNBB (1972). Some have been implemented, and others are under study. In other cases, improvements in existing systems offer substantial short term solutions.

TABLE 67. IRRIGATION IN MANITOBA

BASIN	PROJECT	DAM^3 ALLOCATED
ASSINIBOINE	PRIVATE - SOURIS	2 600
	PRIVATE - ASSINIBOINE	11 800
	TOTAL:	14 400
RED R/L.WINNIPEG	PRIVATE - RED	540
	PRIVATE - PEMBINA	1 600
	PRIVATE - L. MANITOBA	4 400
	PRIVATE - OTHER	2 400
	TOTAL:	8 940
ALL BASINS	TOTAL:	23 340

TOTAL AREA UNDER CROPS (1976) - 9.5×10^6 ACRES

In Alberta, where irrigation is the most widely developed in Canada, considerable effort has gone into evaluating possible future expansions. Recent estimates related to developable land, and irrigable land, are contained in Table 68, to illustrate the dimensions of the varying evaluations.

The most recent estimates are those of Pedology Consultants (1981) and UMA (1981). The latter, prepared for the South Saskatchewan River Basin Planning Program, identifies just over 7 million "potential, commandable irrigable" acres in the basins contributing to the South Saskatchewan River in Alberta. This includes land in Canada Land Inventory soil types 1 to 3, which is accessible to servicing by irrigation works. Of this, UMA considers that improvement of existing works to reach full development of irrigation districts could be achieved by 2000, resulting in a total of 1.6 million acres in the irrigation districts, and 110,000 acres of private irrigation. Expansion beyond that point would (according to UMA) depend upon priorities for development up to the limitations of available water.

The year 2000 expansion would consume about 95 m^3/s of water in an average year. Full development of the 7 million acres would consume nearly 400 m^3/s, assuming a proportional requirement. Far future development would require importation of water.

TABLE 68. ESTIMATES OF DEVELOPABLE AND IRRIGABLE LANDS IN ALBERTA

REGION	ACREAGE	TYPE OF LAND	SOURCE
ALBERTA	2.0 MILLION	CLASS 1 - TOTAL	BENTLEY (1980)
	2.0 MILLION	CLASS 1 - CULTIVATED	
	9.4 MILLION	CLASS 2 - TOTAL	
	9.4 MILLION	CLASS 2 - CULTIVATED	
	15.1 MILLION	CLASS 3 - TOTAL	
	12.1 MILLION	CLASS 3 - CULTIVATED	
	23.0 MILLION	CLASS 4 - TOTAL	
	5.6 MILLION	CLASS 4 - CULTIVATED	
EAST-CENTRAL ALBERTA (6.2 MILLION ACRES)	250 000	FAIR POTENTIAL FOR IRRIGATION (CLASS 2)	PETTAPIECE AND KJEARSGAARD (1980)
	620 000	MARGINAL FOR IRRIGATION (CLASS 3)	
SOUTHERN ALBERTA	1.7 MILLION	ACTUALLY DEVELOPABLE - WITHIN I.D.	PEDOLOGY CONSULTANTS (1980)
	6.2 MILLION	- OUTSIDE I.D.	
SOUTHERN ALBERTA		ACTUALLY DEVELOPABLE OUTSIDE I.D.	PEDOLOGY CONSULTANTS (1980)
	1.1 MILLION	- HIGH NEED LAND	
	1.9 MILLION	- MODERATE NEED LAND	
	3.2 MILLION	- LOW NEED LAND	
ALBERTA	280 000	ESTIMATED PRIVATE IRRIGATION - 1990	BERRY (1979)
	913 500	ESTIMATED IRRIGATION DISTRICTS - 1990	
RED DEER, BOW, OLDMAN, AND S. SASKATCHEWAN	6.14 MILLION	CLASS 1 - IRRIGABLE OUTSIDE I.D.	SCHULER (1980)
	2.08 MILLION	CLASS 2 - IRRIGABLE OUTSIDE I.D.	
	1.53 MILLION	CLASS 3 - IRRIGABLE OUTSIDE I.D.	
RED DEER, BOW, OLDMAN, AND S. SASKATCHEWAN		POTENTIAL COMMANDABLE ACREAGE	UMA (1981)
	1.62 MILLION	- WITHIN EXISTING IRRIGATION DISTRICTS	
	0.11 MILLION	- IN PRIVATE IRRIGATION DEVELOPMENT	
	5.31 MILLION	- IN POTENTIAL NEW BLOCK DEVELOPMENT	

Water transfer between major basins is a controversial subject in Alberta (Chapter II.2), and the provincial government has given no official indication that proposals of that type are planned. A number of factors, including economics, the environment, and water demands in potential donor basins, would be involved.

In Saskatchewan, the South Saskatchewan River Irrigation Project at Lake Diefenbaker, which was originally conceived as the basis for extensive irrigation development, has not yet realized those expectations. Future developments could, however, increase the irrigation role of this reservoir through expansions to the northwest of the Gardiner Dam, additional private irrigation, increased diversion to the Qu'Appelle River, and possible diversion to the southern parts of the province, such as the Souris River basin. (No major development of the latter type has yet been proposed by Saskatchewan.) Expansion of irrigation in the South Saskatchewan, Qu'Appelle and Souris River basins as a result of the above is estimated at about 400,000 acres (Table 69).

TABLE 69. ESTIMATES OF POTENTIAL IRRIGABLE ACREAGE SUPPLIED IN PART FROM LAKE DIEFENBAKER

		ACRES
SOUTH SASKATCHEWAN		
- SSRID		150 000
- SSEWS		20 000
- PRIVATE		100 000
QU'APPELLE		88 000
SOURIS		47 000
	TOTAL	405 000

Irrigation has been slower to develop in Manitoba, but the possibility for a major project exists in the Assiniboine-Hespeler region. An estimated one million irrigable acres exist there, although even full development of storage and diversion from the Assiniboine River, and importation of water from Lake Diefenbaker would not likely result in that amount being realized.

3. OTHER AGRICULTURAL USE

A general discussion of agricultural use of water other than for irrigation is contained in Chapter VII, stock watering and domestic uses being the most significant. More specific detail is presented below for each basin as background for supply/demand assessments in Chapter IV and V.

An important agricultural activity in the Great Plains is the production of livestock. There are an estimated 8.1 million cattle, 2.5 million swine, and 320 000 head of sheep in the Great Plains. Partially supporting the livestock industry is an estimated 104 million acres (42 million ha) of improved and unimproved grazing and forage producing land.

At the present time there is reason to believe that stock populations in western Canada have temporarily stabilized and in some areas are decreasing (see Table 70). However, historical patterns in the numbers of animals have shown cyclic fluctuations with a general increasing trend. Thus, while present livestock populations are not increasing, it is probable that as the market (for red meat especially) improves, there will be increases in stock populations in western Canada. In addition, high costs of grain and potential expansion in the export market for both feed grains and higher grades of grain will extend the need for roughage-based livestock feeding (grazing). It is likely that in the future the initial stages of cattle production (i.e., cow-calf and roughage feeding) will shift to areas which are unsuitable for grain production, while feedlot fattening and finishing of cattle will locate where high protein grain production is carried out (i.e., southern Alberta, central Saskatchewan, and southern Manitoba). This will complicate water demand patterns.

In areas where expansion of grazing occurs, there will be greater need for in-pasture supplies of water, usually dugouts. In areas where feedlots expand, there will also be greater need for good supplies of water. This will probably be water drawn from rivers, reservoirs, or irrigation canals, as ground water and dugouts are often inadequate in supply and quality. Expansion of feedlot operations will create a greater possibility for pollution of water supplies because of the concentration of cattle in small areas.

The rates of increase in cattle population will probably not be as rapid as in the past, due to the high costs of producing beef (a function of the costs of energy, land, and feed,

TABLE 70. STOCK POPULATIONS IN THE PRAIRIE PROVINCES (FITZGIBBON, 1981)

	DAIRY (THOUSANDS)	OTHER CATTLE (THOUSANDS)	HOGS (THOUSANDS)	SHEEP & LAMBS (THOUSANDS)
ALBERTA				
1941-45	366	1 167	1 869	717
1946-50	315	1 295	862	503
1951-55	285	1 637	1 102	366
1956-60	277	2 349	1 455	445
1961-65	280	2 842	1 248	430
1966-70	258	3 198	1 278	259
1971-75				
1976-80		4 359	1 069	177
ANNUAL CHANGE	-1.00%	+6.8%	-0.8%	-1.5%
SASKATCHEWAN				
1941-45	448	1 014	1 128	344
1946-50	372	1 047	452	228
1951-55	298	1 231	542	142
1956-60	253	1 651	687	164
1961-65	208	2 034	507	160
1966-70	124	1 787	617	127
1971-75	96	2 891	844	121
1976-80	74	2 778	551	87
ANNUAL CHANGE	-2.1%	+4.3%	-1.3%	-1.9%
MANITOBA				
1941-45	311	467	553	296
1946-50	263	505	300	132
1951-55	220	536	333	73
1956-60	210	680	390	75
1961-65	178	898	408	71
1966-70	133	967	620	45
1971-75	104	1 124	833	34
1976-80		1 292	718	23
ANNUAL CHANGE	-1.9%	+4.0%	+1.4%	-2.5%

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especially grain). The increases will probably be between three and four percent per year over the next 10 to 20 years, with slightly lower rates in the early eighties. Most of the growth will likely occur in the Oldman, Bow, Athabasca, Peace, South Saskatchewan, and Saskatchewan, as well as the lower Souris and middle Red River basins.

Consumption of water by cattle in Alberta will increase from 196 000 m^3/d in 1981 to 255 000 - 275 000 m^3/d by 1991. In

Saskatchewan consumption will increase from 125 000 m^3/d in 1981 to 160 000 - 175 000 m^3/d by 1991; while in Manitoba consumption by cattle will increase from 58 000 m^3/d to 75 000 - 80 000 m^3/d in 1991.

Use of water by hogs will probably stabilize in the near future in Saskatchewan, Alberta, and Manitoba. Water consumption by hogs in Saskatchewan will remain at, or near, 10 000 m^3/d. In Alberta consumption will probably remain at or near 20 000 m^3/d, while in Manitoba it will increase to 15 000 m^3/d.

Water consumption by sheep has been declining as herd numbers have declined. This trend will probably slow down in the next ten years, and should eventually stabilize as demand from western Canadian markets for fresh mutton and lamb increases. Demand in Alberta for water for sheep will decrease to 1100 m^3/d; in Saskatchewan it will be 500 m^3/d, and in Manitoba it will be 120 m^3/d.

The greatest problem for stock watering will be supplying water for cattle. There will also be some problem with supplies for hogs on a local basis. In addition to the direct consumption by the animals, water is consumed in evaporation and percolation from reservoirs, though the latter may eventually return to surface systems or be of use as ground water. In the case of feedlots, large volumes of water may also be involved in the dilution of wastes.

TABLE 71. FARM POPULATIONS IN THE PRAIRIE PROVINCES
(FITZGIBBON, 1981)

YEAR	ALBERTA	SASKATCHEWAN	MANITOBA
1941	383 964	N/A	N/A
1946	335 610	N/A	224 919
1951	345 222	N/A	219 233
1956	373 191	362 231	202 163
1961	287 814	305 740	172 946
1966	281 585	281 089	161 662
1971	237 924	233 792	131 202
1976	219 302	202 715	114 115
AVERAGE ANNUAL CHANGE	-1.07%	-1.76%	-1.4%

TABLE 72. CONSTRAINTS ON STOCKWATERING, BY BASIN (FITZGIBBON, 1981)

	OLDMAN	BOW	RED DEER	S.SASK.	N.SASK.	BATTLE	SASK.	QU'APPELLE	ASSINIBOINE	SOURIS	RED	L.WINNIPEG	MISSOURI	ATHABASCA	PEACE
- DEMAND ($10^3 M^3$/DAY)	23	15	22	24	58	17	7	19	30	20	17	13	23	15	14
- % OF DRAINAGE	5	1.5	LT 1	LT 0.5		5			LT 2	0.5	LT 0.1		LT 0.5		
- MODERATE SUPPLY CONSTRAINTS			C			U		C,L	U		L		T		C
- SEVERE SUPPLY CONSTRAINTS	C,L													U	
- LOCAL QUALITY CONSTRAINTS							T								
- WIDESPREAD QUALITY CONSTRAINTS	C,L	C,L	T	T		T			T			T	T		T
- LOCAL QUALITY EFFECTS	T							T				T			
- WIDESPREAD QUALITY EFFECTS		T	T	T		T			T		T				T
- EXPANSION LIKELY		T	T	T			T								
- EXPANSION UNLIKELY	T							T							

U - UPPER BASIN
C - CENTRAL BASIN
L - LOWER BASIN
T - THROUGHOUT
LT - LESS THAN

TABLE 73. CONSTRAINTS ON FARM HOUSEHOLD WATER USE BY BASIN
(FROM FITZGIBBON, 1981)

	OLDMAN	BOW	RED DEER	S. SASK.	N. SASK.	BATTLE	SASK.	QU'APPELLE	ASSINIBOINE	SOURIS	RED	L.WINN.	MISSOURI	ATHABASCA	PEACE
- DEMAND ($10^3 M^3$/DAY)	3.7	4.4	5.1	10.2	42.3	5.8	2.7	9.9	11.9	8.5	7.8	3.8	5.7	3.1	9.5
- MODERATE SUPPLY CONSTRAINTS						C									
- SEVERE SUPPLY CONSTRAINTS										UL			T		
- LOCAL QUALITY CONSTRAINTS									CL			T			
- WIDESPREAD QUALITY CONSTRAINTS	C,L	L	T	T	CL	T	T	T	U	T			T	T	T

U - UPPER BASIN
C - CENTRAL BASIN
L - LOWER BASIN
T - THROUGHOUT

Farm populations in the west have, in general, been declining for the past 20 to 40 years (Table 71). This decline has been at an average rate of 1.0 to 1.75 percent per year, due to the expansion of acreages which can be economically farmed in the west and the improvement of technology available to farmers. Average farm size in the three prairie provinces ranges from 950 acres (385 ha) in Saskatchewan to 815 acres (330 ha) in Alberta, to 595 acres (240 ha) in Manitoba. The extent to which farm units can expand will depend on further mechanization, and the extent to which farming remains a family rather than a corporate business. It is suggested (Manitoba Agriculture, 1978) that the size of farms will increase 20 percent over the next decade, implying that there will be a further reduction in farm population. This does not mean that there will be an equivalent reduction in water demand on farmsteads, because per capita water demand has increased drastically in the last 20 years.

The outcome of these two offsetting tendencies will probably be a slight decline in farmstead water use overall (i.e., 0.2 to 0.4 percent decrease per annum). However, the consolidation of farms will result in a larger demand at individual farmsteads. This will result in more frequent shortfalls at these sites and a more severe problem for farmstead water supply.

The FitzGibbon report (1981) provides details of other agricultural uses, including present constraints, and the effects of usage on waters receiving effluent, for each of the basins included in this study. A summary has been prepared in Tables 72 and 73.

These tables contain information pertaining to agricultural demands for water in basins that are partly in British Columbia or the Northwest Territories. In basins tributary to the Mackenzie River other than the Peace and Athabasca, little agricultural activity takes place. This is not to say that there is no potential. The agricultural activity that does take place is of great local importance since it represents a stable and diversifying factor in the local economy. Further, it provides much needed fresh foodstuffs of high quality without the high cost of transportation.

There is cattle and grain production in the Keg River area, some of which lies in the Hay River Basin. There is also some agricultural activity in the Slave River basin south of Fort Smith. In addition there is cattle and grain production around Watson Lake in the Laird Basin. In these areas there is generally sufficient moisture so that water supply and quality do not represent a problem. The major problems are caused by freezing of water systems in the winter.

It can be readily seen that stockwatering and domestic uses throughout the drainage to Hudson Bay and the Missouri River, except for the more northern basins, experience considerable constraints, due in part to reliance on small local supplies (e.g., dugouts) that suffer in dry years, and in part to widespread quality problems in wells and dugouts. These problems are often aggravated by local contamination due to agricultural usage.

Water quality problems vary from place to place, but include salinity problems in wells and sloughs, algal growth on dugouts, and contamination of wells by iron, bacteria, nitrates, and sulphates.

These quantity and quality problems are not easily addressed because large scale transport of water from rivers or lakes is not practical for these purposes. In some basins, substantial expansions of stockwatering needs are unlikely, due to these constraints. Although, for example, the total demand for stock water could be expected to increase by 35 percent in Alberta, the figure is not likely to be reached due to high pressure on grazing lands (FitzGibbon, 1981).

4. INDUSTRIAL USE

Industrial uses in the Study Region are many and varied, though in many of the basins examined they are not highly consumptive. This section deals with industries that are self-supplied with water, and much of the information that follows is derived from MacLaren (1980). Industries which draw upon municipal supplies are discussed in the municipal use category in the next section.

Saskatchewan-Nelson Drainage

Within the Saskatchewan-Nelson drainage region (Table 74), it is estimated that 50 percent of the surface water presently withdrawn for industrial use is in the North Saskatchewan River basin. The largest consumer of water in the entire region is the petroleum, coal, and chemical products group, which withdraws in the order of 210 000 m^3/d, while consuming about 26 percent. The forest products industry also withdraws a relatively large volume of water, but this is not widespread, being predominantly for the pulp and paper industry near Prince Albert, Saskatchewan.

The petroleum, coal and chemical products group withdraws an estimated 180 000 m^3/d of surface water in the North Saskatchewan River basin. The water is used in several large petroleum refineries and gas processing plants, and in the manufacture of chemical products such as fertilizer, ammonia, sulphuric acid, copper sulphate, herbicides, wood preservatives, and antifreeze.

According to a 1976 Alberta survey, greater than one- half of the water withdrawn in petroleum and chemical products industries in this basin is consumed. However, using Tate's (1980) national consumptive indices of 5.1 and 6.5 percent, the consumption is estimated to be much smaller. The consumption reported in the Alberta survey, however, is used in the Table (see note 2).

The second largest water user in this basin is the forest products industry, in which bleached kraft pulp is produced near Prince Albert. Estimates of withdrawal and consumption for this industry were derived from the number of employees, using Tate's indices.

Mines and quarries using water in the North Saskatchewan basin include coal, salt, and sodium sulphate. Non-metallic mineral products include production of cement and concrete.

Table 74. Estimated self-supplied industrial use of surface water in the Saskatchewan-Nelson drainage basin (m^3/d)
(not including water used for oil field injection)
(MacLaren, 1980)

Sub-basin	Mines & Quarries	Food & Beverage	Petroleum Coal & Chemical Products	Forest Products	Non-Metallic Mineral Products	Miscellaneous	Total
N. Saskatchewan (A,B)							
Withdrawal	25 100[1]	400	75 000	81 000	3 500[1]	2 000	187 000
Consumption	4 000	0	46 000[2]	3 000	300	0	53 300
Red Deer (A)							
Withdrawal	-	-	12 000	-	100	-	12 100
Consumption	-	-	600	-	0	-	600
Bow (A)							
Withdrawal	-	3 000[3]	80 000[4]	-	5 000	-	88 000
Consumption		200	5 000	-	100	-	5 300
Oldman (A)							
Withdrawal	12 400[5]	9 000	8 000[6]	-	500	100	30 000
Consumption	5 600	500	400	-	0	0	6 500
S. Saskatchewan (A,B)							
Withdrawal	1 500	-	35 000[7]	-	-	200	36 700
Consumption	100	-	2 000	-	-	0	2 100
Saskatchewan (C)							
Withdrawal	6 000[8]	-	-	-	-	-	6 000
Consumption	200	-	-	-	-	-	200
Cypress Hills (B)							
Withdrawal	-	100[9]	-	-	-	-	100
Consumption	-	0	-	-	-	-	0
Qu'Appelle (B)							
Withdrawal	6 500[10]	-	-	-	-	-	6 500
Consumption	6 500	-	-	-	-	-	6 500
L. Winnipegosis (B)							
Withdrawal	-	-	-	500	-	-	500
Consumption	-	-	-	0	-	-	0
Nelson (C)							
Withdrawal	6 100[11]	-	-	-	-	-	6 100
Consumption	600						600
Total							
Withdrawal	57 600	12 500	210 000	81 500	9 100	2 300	373 000
Consumption	17 000	700	54 000	3 000	400	0	75 100

* Numbers in superscripts refer to the notes that follow

Notes to Table 74 (from MacLaren, 1980)

1. There appeared to be some confusion in classifying plants in the Alberta Survey as Mines and Quarries and Non-Metallic Mineral products in Alberta. In this report, they are classified, hopefully logically, from the water licences.
2. The high consumption figures for Petroleum, Coal and Chemical Products may result from injection of the effluent to ground water.
3. The two licensed Food and Beverage Plants were not interviewed as part of the questionnaire.
4. This figure is generous, when compared to the licensed withdrawal and withdrawal calculated on the basis of employment. However, it is only half of what was reported in the questionnaire.

Table 74 Notes Continued

5. Coleman Collieries was not interviewed in the 1976 questionnaire. A recent agreement for export by Coleman Collieries to Japan will increase the significance of the Collieries use of water in the Oldman Basin.

6. The Picture Butte sugar refinery has been closed since the 1976 questionnaire. Therefore, use of water in the Food and Beverage Industry is somewhat lower.

7. The questionnaire reported about 10,000 m^3/d for use in the chemical industry, but only one of the two plants was interviewed. Moreover, there are two gas plants in the Alberta portion of the basin that were not interviewed. Therefore, it is suggested that the questionnaire results are low and a more reasonable value is presented in the table.

8. Based on the withdrawal/employee index, the withdrawal is estimated to be 6,000 m^3/d. Consumptive use is based on 3.6%, the average for metal mines in Manitoba (Tate, 1980).

9. Based on the withdrawal/employee index, the estimated withdrawal is 100 m^3/d, for use in the production of sodium sulphate.

10. Water licensed for industrial use in the Qu'Appelle Basin is used in the potash industry.

11. In the Nelson sub-basin, industrial water use is limited to the mining and processing of copper and zinc ores.

Sources:

a) Alberta withdrawal and consumption patterns were estimated by preparing a chart for each sub-basin as follows:

- All plants licensed and authorized to withdraw surface water by Alberta Environment were grouped according to SIC classification. Licensed withdrawal was listed. This was multiplied by a consumption index for each industrial classification (Tate, 1980) to give approximate consumption.
- The number of employees of each licensed plant (Alberta Economic Development, 1979) was multiplied by a withdrawal/employee index (as calculated by Tate, 1980) for Alberta to estimate withdrawal. The withdrawal figure was multiplied by Tate's consumption index to give an estimate of consumption.
- The withdrawal and consumption as reported by Alberta Environment (1979c) on a computer printout prepared as a result of a 1976 questionnaire survey were used.

These three sets of withdrawal and consumption figures were compared and a set of withdrawal and consumption figures was selected to best represent the withdrawal and consumption pattern.

b) Saskatchewan withdrawal and consumption were estimated by preparing a chart for each sub-basin as follows:

- All plants licensed to withdraw surface water by the Saskatchewan Department of Environment were grouped according to SIC classification. Licensed withdrawal was listed. This was multiplied by a consumption index for each industrial classification (Tate, 1980) to give approximate consumption.
- The number of employees of each licensed plant (Saskatchewan Industry and Commerce, 1979) was multiplied by a withdrawal/employee index for Saskatchewan (as calculated by Tate, 1980) to estimate withdrawal. The withdrawal figure was multiplied by Tate's consumption index to give an estimate of consumption.

These two sets of figures were compared and a set of withdrawal and consumption figures was chosen to represent the withdrawal and consumption pattern.

c) Manitoba withdrawal and consumption patterns were estimated by preparing a chart for each sub-basin as follows:

- All plants licensed to withdraw surface water by the Manitoba Department of Environment were grouped according to SIC classification. Licensed withdrawal was listed. This was multiplied by a consumption index for each industrial classification (Tate, 1980) to give approximate consumption.
- The number of employees of each licensed plant (Manitoba Department of Economic Development and Tourism, 1979) was multiplied by a withdrawal/employee index for Saskatchewan (as calculated by Tate, 1980) to estimate withdrawal. The withdrawal figure was multiplied by Tate's consumption index to give an estimate of consumption.

These two sets of figures were compared and a set of withdrawal and consumption figures was chosen to represent the withdrawal and consumption pattern.

Government and industry forecasts predict growth for all industrial sectors in this basin. As new technology is developed, withdrawal and consumption of water may be decreased in the various industrial processes. However, it is expected that the growth of industry and associated water use will exceed these savings (MacLaren, 1980).

The most rapid growth will undoubtedly take place in the petroleum and chemical products industries. Esso Resources could be required to pump water from the North Saskatchewan River to its Cold Lake oil sands recovery plant in the Churchill River basin (Chapter II.2). Because of delays in federal-provincial oil price negotiations, construction of the Cold Lake facility was suspended in 1981. The project would produce in the order of 22 000 m^3 of synthetic crude per day, requiring 93 000 m^3/d (1 m^3/s) of water, 57 percent of which would be consumed in operations (Table 81) (ERCB, 1979). Ryckborst (1981) estimates that oil sands developments using North Saskatchewan River water will require about 1.7 m^3/s for a plant producing 25 000 m^3/d with no recycling. He further suggests that a production of 320 000 m^3/d could occur, requiring a water diversion of up to 21 m^3/s without recycling. These estimates are somewhat higher than from other sources because some degree of recycling is usually assumed. Assuming 40 percent recycling, a production rate of 100 000 m^3/d would require about 4 m^3/s. Any large degree of expansion of heavy oil and oil sands development adjacent to or in the North Saskatchewan River basin would make extensive demands on that supply or on outside supplies such as the Athabasca River system.

In Saskatchewan, water requirements for heavy oil development are expected to be much smaller. The forecast requirement by 1989 is 0.14 m^3/s (Table 75).

Shell Canada has been given approval by the Alberta Energy Resources Conservation Board to construct a refinery for synthetic crude oil in the Edmonton area. If approved by the Alberta Cabinet, the plant would commence operation in 1984. Synthetic crude would be refined from the Suncor and Syncrude plants initially, and later from the anticipated cold Lake and Alsands developments. Water withdrawal is expected to be 0.3 m^3/s, while return flow values are not yet known. Additional refinery developments along the North Saskatchewan River could require between three and six m^3/s supply in the foreseeable future (Alberta Environment).

TABLE 75. FORECAST OF HEAVY OIL DEVELOPMENT WATER REQUIREMENTS IN SASKATCHEWAN
(SASK. MINERAL RESOURCES, 1981)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
					(BARRELS x 10^6)*					
DRILLING	0.8	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.6	0.6
TERTIARY RECOVERY	0.2	0.2	1.1	2.9	7.8	10.0	12.1	17.7	14.9	20.2
UPGRADER OPERATIONS	0	0	0	0	0	0	7.3	7.3	7.3	7.3
TOTAL	1.0	1.0	1.9	3.6	8.5	10.7	20.0	25.6	22.8	28.1

* 10^6 BARRELS/YR IS EQUIVALENT TO 0.005 M^3/S

The petroleum and chemical products industry is also the largest water user in the Red Deer River basin (Table 74). There are several gas processing plants, and the Alberta Gas Ethylene Plant at Joffre, near Red Deer, which came into operation in 1978. Alberta Gas Ethylene is applying to build a second plant in Joffre, and additional industrial development can be expected near Red Deer. The establishment of six petrochemical plants in this region would require up to 0.6 m^3/s of water supply (ECA, 1977).

In the Bow River basin, the petroleum, coal and chemical products group is the largest industrial water user. Within the chemical industry, the water is used largely in the manufacturing of ammonia and fertilizer products. In the oil and gas industry, the water is used in the production of petroleum products and gas processing. A substantial amount of water is used in the non-metallic mineral products industry, mainly for the production of concrete and cement used in the construction industry in the Calgary area.

There are only two plants in the food and beverage industry which do not withdraw water from municipal sources. One produces potato products in the Vauxhall area and the other produces meat products in the Brooks area.

A recent analysis of an area within a 35 to 55 km radius of Calgary indicates that "...no major industrial developme[illegible] are foreseen..." (Alberta Environment, 1980a).

Industrial water use in the Oldman River basin (Table 74) is divided fairly evenly among the mines and quarries; food and beverage; and petroleum, coal, and chemical products categories. A small amount of water is used in the non-metallic mineral products industry and the electrical products (miscellaneous) industry.

In the mines and quarries category, water withdrawals are all due to coal mining. Although production has been low in recent years, the recent signing of an export agreement with Japan is expected to increase production significantly. One coal development in the Lethbridge area is expected to be in operation by 1985 and at least two other developments are being studied.

Most of the water used by the food and beverage industry is used in the processing of sugar beets at Taber. There are two gas processing plants licensed to withdraw water in this basin, both located near Pincher Creek.

The South Saskatchewan River basin straddles the southern Alberta and Saskatchewan border area. Some industrial uses of water are in the petroleum and chemical products industry in the Alberta portion of the basin, where two fertilizer plants and a gas processing plant are licensed to withdraw surface water. A methanol plant expansion and a feasibility study for a coal gasification plant are indicated for the Medicine Hat Region (Major Projects Task Force, 1981). Potash mining in this basin in Saskatchewan is supplied mainly by the Water Supply Board from a northeastward diversion from Lake Diefenbaker (Chapter II.2). In 1980 this supply provided the potash industry (five plants) with about 0.15 m^3/s, which is not included in Table 74. One additional plant in this basin is self-supplied.

Major potash mine rehabilitation has been completed or is scheduled for completion at Cory and Lanigan within the next four or five years. There may be a marginal increase in water use associated with this program. Another of the plants supplied by the Water Supply Board is expected to increase production by 50 percent in the foreseeable future. A new potash mine is being planned to come on stream at Bredenbury in 1986, three times as large as any of the existing mines. Considering the above, it is not unreasonable to project that about 0.5 m^3/s of water supply could be consumed by this industry in this basin by 1990. A major fertilizer plant requiring up to 0.5 m^3/s is planned for location in either this basin or the Qu'Appelle River basin, and a heavy oil up-grader is expected near Saskatoon, requiring about 0.2 m^3/s (City of Saskatoon).

In the remaining portions of the Saskatchewan-Nelson basin, the industrial use of surface water is less, mostly in the mines and quarries group. Withdrawals and consumption for this category total 18 600 m^3/d and 1400 m^3/d, respectively (Table 74). These figures do not include approximately 10 000 m^3/d licensed to a potash mine near Regina in the Qu'Appelle River basin, all of which is consumed. The forest products industry in the Lake Winnipegosis basin withdraws about 500 m^3/d, consuming very little.

In some locations of this region, industrial plants withdraw water from ground water or from municipal supplies. Potash mines in the lower Qu'Appelle River basin, for example, rely mainly on ground water supplies, although approximately 6500 m^3/d is licensed from surface waters for one of the mines (Table 74). There is one exception in the City of Winnipeg, where a sugar beet refinery withdraws 2000 m^3/d from the Red River to be used as cooling water, on a seasonal basis. Production water is withdrawn from the municipal system.

Although the mining industry has been sluggish in Manitoba for the past few years, exploration for minerals has been fairly intensive. Base metals, gold, and uranium are the major minerals of interest. Potash mining is expected to begin in Manitoba near St. Lazare in the Assiniboine River basin.

A uranium refinery proposed at Warman, north of Saskatoon, has been delayed as a result of potential social impacts. A new site is being sought in the same general area. The possibility of the location of an aluminum smelter near Winnipeg is being explored by the Aluminum Company of Canada. Although this plant would require about 400 MW of hydro power, its use of process water is expected to be low.

Future growth of the food and beverage and non-metallic minerals industries will depend to a large extent on developments in the resource industries and the location of population growth. Food and beverage plants generally use municipal water supplies, except in Manitoba, where ground water is used. Non-metallic minerals plants usually have their own sources of surface or ground water.

Table 76. ESTIMATED SELF-SUPPLIED INDUSTRIAL USE OF GROUND WATER IN THE SASKATCHEWAN-NELSON DRAINAGE BASIN

(not including water used for oil field injection)
(MacLaren, 1980)

Sub-basin[1]	Withdrawal (m^3/d)
North Saskatchewan (A,B)	4 300[2]
Red Deer (A)	900[3]
Bow (A)	8 000[4]
South Saskatchewan (A)	7 500[5]
Saskatchewan (A,B)	100[6]
Cypress Hills (B)	4 000[7]
Qu'Appelle (B)	16 100[8]
Souris (B)	200[9]
Lake Winnipeg (B)	4 500[10]
Red River (B)	5 000[11]
TOTAL	50 600

* Numbers in superscripts refer to the notes that follow

Notes to Table 76 (from MacLaren, 1980)

1. This table includes only those basins which use 100 m^3/d of ground water for industrial purposes.
2. This includes both the Alberta and Saskatchewan portion of the basin. The amount of ground water withdrawn for industrial use in the Alberta portion of the basin was reported to be three times greater in the 1976 questionnaire than the 1980 licensed allocation. It appeared that some use in oil field injection had been included in the questionnaire. Therefore, an approximate value of 1500 m^3/d was suggested for the Alberta portion. According to the licences, ground water is allocated for the Mineral Fuels, Food and Beverage and Non-Metallic Mineral Industries. According to the questionnaire, ground water is also used in the Petroleum and Coal Products and Forest Products Industries.
3. The licensed withdrawal and withdrawal reported in the questionnaire were within 200 m^3/d. An average value of 800 m^3/d was felt to be representative. Ground water is used in the following industries: Food and Beverage, Petroleum, Coal and Chemical Products and Non-Metallic Mineral Products.
4. Ground water use in the Bow River Basin is not clear. A withdrawal of 3000 m^3/d is licensed, mainly for use in the Food and Beverage, Chemical products and Non-Metallic Mineral industries. With respect to the latter, the Alberta Environment data shows that 24 million m^3/yr of ground water are used in the ready mix concrete industry in the Bow River Basin. This seemed excessive, thus the Alberta Redi-Mix Concrete Association was contacted. They estimate that 1.5 million cubic metres of concrete is produced in the Calgary area annually. This translates to 1620 m^3/d of water. From the water licence and employment information, it is estimated that less than 1000 m^3/d of surface water is used in the ready mix industry in the Bow River Basin. Therefore, approximately 1000 m^3/d of ground water may be appropriate.

   If it is assumed that the ground water withdrawn is between the licensed amount and that ascertained by the questionnaire, with the revised ready mix information it can be estimated that approximately 8000 m^3/d of ground water is used for industrial purposes in the Bow River Basin.

Notes to Table 76 Continued

5. This includes both the Alberta and Saskatchewan portion of the basin. There is no licensed ground water withdrawal from the South Saskatchewan Basin in Alberta. However, in the 1976 questionnaire, a withdrawal of 7000 m^3/d was reported. Most of this was in the Petroleum and Coal Products Industry. In the Saskatchewan portion, about 500 m^3/d is licensed for withdrawal by the Food and Beverage Industry.

6. Approximately 100 m^3/d is withdrawn from ground water by Food and Beverage and Miscellaneous Industry.

7. This water is utilized by the Sodium Sulphate Mining Industry.

8. Ground water is used by the following: Food and Beverage, Mines and Quarries, Non-Metallic Minerals, Metal Industries and Petroleum, Coal and Chemical Products. The total of 9,100 m^3/d does not include two new plants (Cominco and the Canadian Co-op Refinery) which do not have allocations specified in their authorizations. It should be noted that International Mineral and Chemical Corporation (Potash Mine) is licensed to withdraw both surface (6,000 m^3/d) and ground water (3,000 m^3/d).

9. Ground water is used by the Coal Mining Industry in the Saskatchewan portion of the Souris Basin.

10. The Food and Beverage Industry is the sole industrial user of ground water in the Lake Winnipeg Basin.

11. All water used for industrial purposes in the Red River Basin is drawn from ground water. Most of this water is used by the Food and Beverage and Metal Industries.

Sources:

A) Alberta withdrawal patterns were estimated using the following:

- The quantity of water allowed by Alberta Environment water licences and authorizations.
- The withdrawal computed for licensed plants using the number of employees (Alberta Economic Development, 1979) and Tate's withdrawal/employee ratio.
- The withdrawal reported by Alberta Environment (1979) on a computer printout prepared as a result of a questionnaire survey.

These three sets of withdrawal figures were compared and a set of withdrawal figures was chosen to take known variables into account.

B) Saskatchewan and Manitoba withdrawal patterns were estimated using the following:

- The quantity of water allocated in the water licences.
- The withdrawal computed for licensed plants using the number of employees (Saskatchewan Industry and Commerce, 1979; Manitoba Department of Economic Development and Tourism, 1979) and Tate's withdrawal/employee ratio.

These two sets of figures were compared and a set of withdrawal figures was chosen to take known variables into account.

Ground water withdrawal in the Saskatchewan-Nelson basin is estimated in Table 76. Ground water plays a more significant role in the southern river basins where surface water supplies are not always plentiful. The type of industry using water in each of the basins is outlined in the notes accompanying the Table.

The withdrawal quantities suggested in Table 76 are very general, and there appears to be little agreement in some of the Alberta basins between the data collected in the 1976 questionnaire and the water licenses for the various industrial sectors. However, there was some uniformity in the total quantity of ground water withdrawn in each basin. The use of ground water by industry or the conjunctive use of surface and ground water may increase in the more southerly basins.

TABLE 77. WATER USED FOR OIL FIELD INJECTION IN ALBERTA (m^3/d) (MACLAREN, 1980)

RIVER BASIN	LICENSED AND AUTHORIZED (A) (1980)	WATER USED IN 1979 (B)		
		TOTAL	GROUND WATER	SURFACE WATER
MACKENZIE				
ATHABASCA	151 000	71 500	6 500	65 000
PEACE	60 700	30 700	8 400	22 300
SASKATCHEWAN-NELSON				
NORTH SASKATCHEWAN	109 000	50 700	10 700	40 000
RED DEER	25 300	14 900	5 900	9 000
BOW	26 600	10 000	2 200	7 800
OLDMAN	1 900	100	-	100
SOUTH SASKATCHEWAN	3 500	3 500	1 200	2 300
MISSOURI	-	100	100	-
CHURCHILL	21 200	100	-	100
TOTAL	399 200[1]	181 600	35 000	146 600

NOTES:

1. THE TOTAL WATER USED WAS EQUAL TO ABOUT 45% OF THAT AUTHORIZED AND LICENSED FOR USE BY ALBERTA ENVIRONMENT.

SOURCES: (A) ALBERTA ENVIRONMENT (1980b)
(B) ENERGY RESOURCES CONSERVATION BOARD, 1980

Water is used for oil field injection in Alberta and Saskatchewan. In Alberta, almost 400 000 m^3/d of water are allocated by water licenses to oil field injection (Table 77). In 1979, the Energy Resources Conservation Board examined actual water used by industry in oil field injection. This is compared to the licensed allocation for each basin in the Table. Actual use was approximately 45 percent of the licensed allocation in 1979, which is the same for most of the individual basins. Approximately 80 percent of the water used for oil field injection is surface water.

The largest quantity of water used for oil field injection is in the Athabasca basin, followed by the North Saskatchewan and Peace River basins. The only basin for which there is a large discrepancy between the licensed allocation and reported use is the Churchill basin, where recent licenses/authorizations in the vicinity of Cold Lake will probably not be developed until the Esso project is approved.

TABLE 78. GROUND WATER[1] LICENSED FOR OIL FIELD INJECTION IN SASKATCHEWAN (M^3/D)
(MACLAREN, 1980)

RIVER BASIN		LICENSED WITHDRAWAL (1980)[2]
SASKATCHEWAN - NELSON		
	NORTH SASKATCHEWAN	13 900
	SOUTH SASKATCHEWAN	6 800
	CYPRESS HILLS	13 200
	QU'APPELLE-ASSINIBOINE	2 700
	SOURIS	40 900
MISSOURI		
	OLD WIVES LAKE	300
	MISSOURI	3 200
TOTAL		81 000

NOTES:

1. THERE WERE NO SURFACE WATER LICENCES FOR OIL FIELD INJECTION IN SASKATCHEWAN IN THE LISTING PROVIDED BY SASKATCHEWAN ENVIRONMENT
2. THIS IS WATER LICENSED FOR USE. ACTUAL USE IS LIKELY SOMEWHAT LESS THAN THIS FIGURE. IN ALBERTA, ACTUAL USE WAS APPROXIMATELY 45% OF LICENSED USE IN 1979.

In Saskatchewan, 81 000 m^3/d of ground water is licensed for oil field injection (Table 78). The largest quantity licensed for use is in the Souris River basin, with some in the North Saskatchewan basin (Lloydminster area) and the Cypress Hills.

Missouri River Drainage

The Missouri River drainage includes the Old Wives Lake internal drainage system and all other tributaries which drain southward to the Missouri River. To the present time there has been virtually no industrial development in this region, and neither the Alberta nor the Saskatchewan governments is predicting significant future industrial growth. Water is licensed for the mining and production of sodium sulphate, but consumption is essentially zero (Tate, 1980). There is only one ground-water license in the basin (less than 50 m^3/d) for use in the dairy products industry. There is no licensed water withdrawal for industrial purposes in the Milk River basin in southern Alberta. This is essentially the driest area of the prairie provinces and industry is not likely to develop here, except for extractive purposes such as sodium sulphate production.

TABLE 79. ESTIMATED SELF-SUPPLIED INDUSTRIAL USE OF SURFACE WATER IN THE CHURCHILL RIVER DRAINAGE BASIN (M^3/D)
(NOT INCLUDING WATER USED FOR OIL FIELD INJECTION)
(MACLAREN, 1980)

	MINES & QUARRIES	TOTAL
WITHDRAWAL	10 000[1]	10 000
CONSUMPTION	200[2]	200

NOTES (FROM MACLAREN, 1980):

1. THIS WITHDRAWAL FIGURE INCLUDES THE LICENSED WITHDRAWAL FOR URANIUM MINING AT RABBIT LAKE, SASKATCHEWAN AND THE LICENSED WITHDRAWAL FOR THE SHERRITT GORDON MINES (NICKEL, COPPER, ZINC) IN MANITOBA.
2. THIS CONSUMPTION FIGURE IS BASED ON TATE'S CONSUMPTION INDICES.

SOURCES: THE WITHDRAWAL AND CONSUMPTION PATTERN WAS ESTIMATED BY PREPARING A CHART AS FOLLOWS:

THE PLANTS LICENSED TO WITHDRAW WATER BY THE SASKATCHEWAN DEPARTMENT OF ENVIRONMENT WERE GROUPED ACCORDING TO SIC CLASSIFICATION. LICENCED WITHDRAWAL WAS LISTED. THIS WAS MULTIPLIED BY A CONSUMPTION INDEX (TATE, 1980) TO GIVE APPROXIMATE CONSUMPTION.

THE NUMBER OF EMPLOYEES OF EACH LICENSED PLANT (SASKATCHEWAN INDUSTRY AND COMMERCE 1979) WAS MULTIPLIED BY A WITHDRAWAL/EMPLOYEE INDEX FOR SASKATCHEWAN (AS CALCULATED FROM TATE, 1980) TO ESTIMATE WITHDRAWAL. THE WITHDRAWAL FIGURE WAS MULTIPLIED BY TATE'S CONSUMPTION INDEX TO GIVE AN ESTIMATE OF CONSUMPTION.

THESE TWO SETS OF FIGURES WERE COMPARED AND A SET OF WITHDRAWAL AND CONSUMPTION FIGURES WAS CHOSEN TO REPRESENT THE WITHDRAWAL AND CONSUMPTION PATTERN.

Water is licensed in the Churchill River basin (Table 79) primarily for use in the mining industry, although there is also one license for 50 m^3/d for a fish processing plant. There are no ground water licenses in the basin except for oil well injection, described earlier in this section.

In the Saskatchewan portion of the basin, water is licensed for use (0.6 m^3/s) at the Rabbit Lake uranium mine in the Wollaston Lake area, where uranium has been mined for the past ten years. According to Tate's study, consumptive use in the uranium mining industry is very small. Saskatchewan Environment is presently reviewing all aspects of water use in this industry, in part to determine consumptive usage. In the Manitoba portion, water is licensed for use in the mining of base metals (nickel, copper and zinc). Tate's index was used to calculate consumptive use in the mining industry.

The Cold Lake Oil Sands development which is awaiting a federal-provincial agreement on oil prices would be located in the Churchill drainage basin. Although it could withdraw water from the North Saskatchewan River, the possibility still exists that supply would come from local surface waters. Treated waste water will likely be discharged to the Churchill system.

Uranium mining will probably increase in the Churchill River basin in the future. A mine at Key Lake is being planned and the environmental reports have been submitted to the government for public review (see Key Lake Board of Inquiry, 1981). Expansion of the Rabbit Lake Mine (Collins Bay) is in the planning stages, and an environmental impact statement for the development of a uranium ore body at Midwest Lake is being prepared. Other substantial ore bodies have been discovered. Their development will depend on future world markets.

In other basins draining to Hudson Bay, there has been sporadic exploration and development of mineral resources. In late 1981, a gold mine near Cullaton Lake is expected to commence operation, and another is expected to be developed nearby. However, of perhaps more interest to water managers is the prospect for uranium development in the District of Keewatin. The most likely initial site is just west of Baker Lake, with other possibilities some 150 km northwest and 200 km southwest of Baker Lake. These developments are possible over the next 5 to 10 years, and are the subject of some concern regarding potential effects on the environment and human health. A number of studies were underway during 1981, including two under the Arctic Land Use Research program (ALUR).

Table 80. Estimated self-supplied industrial use of surface water in the Mackenzie River drainage basin (m^3/d)
(not including water used for oil field injection)
(MacLaren, 1980)

Sub-basin	Mines & quarries	Petroleum coal & chemical products	Forest products	Non-metallic mineral products	Total
Athabasca River (a)					
withdrawal	1 500^{2}	242 000^{3}	86 000^{4}	800^{5}	330 300
consumption	700	220 000	4 000	0	224 700
Peace River (a,b)					
withdrawal	0	12 000	82 000	100	94 100
consumption	0	10 000	20 100^{6}	0	30 100
Liard River (a,b,c)					
withdrawal	4 000	-	-	-	4 000
consumption	200	-	-	-	200
Mackenzie River (c)					
withdrawal	0	4 000	-	-	4 000
consumption	0	200^{7}	-	-	200
Great Slave Lake (c)					
withdrawal	24 900^{8}	-	-	-	24 900
consumption	5 900	-	-	-	5 900
Great Bear Lake (c)					
withdrawal	1 900^{9}	-	-	-	1 900
consumption	200	-	-	-	200
Total					
withdrawal	32 300	258 000	168 000	900	459 200
consumption	7 000	230 200	24 100	0	261 300

* Numbers in superscripts refer to the notes that follow

Notes to Table 80 (from MacLaren, 1980)

1. All figures are rounded to the nearest 100 m^3/d. Withdrawal or consumption of less than 50 m^3/d is rounded to zero; withdrawal of greater than 50 m^3/d is rounded to 100. There is a fish processing plant on Slave Lake, but it only withdraws 30 m^3/d, therefore it is not included.
2. There are 3 collieries licensed to use water in the Athabasca basin. One of these was interviewed in the 1976 Water Use Survey. Therefore, a figure close to the licensed withdrawal was used. Consumptive use was estimated to be 45% (Tate, 1980). There are two uranium mines in the Lake Athabasca Basin. Eldorado Nuclear, at Uranium City does not have a water licence. Amok at Cluff Lake has a licence, but a quantity of withdrawal is not specified. Based on the questionnaire and the Rabbit Lake licence, (Churchill Drainage Basin) withdrawal of the two mines may be 5,000-10,000 m^3/d and consumptive use would be zero.
3. This includes a number of gas plants, Syncrude and Suncor. The withdrawal and consumption figures for Syncrude were obtained by contacting Syncrude. The figures for the other users were estimated from the sources listed below.
4. The Forest Products Industry is licensed to use 2.5 times as much water as reported in the 1976 survey. The survey data were selected to be representative of the forest products industry in the Athabasca Basin. Similar values were reported by Miller (1980).
5. Non-Metallic Mineral Products were not included in the 1976 survey of the Athabasca Basin. Three concrete plants were listed in the water licences. Two of these were licensed in 1978 and 1980, after the questionnaire. Therefore, water withdrawal is estimated on the basis of employment.
6. The consumptive use in the Peace River sub-basin is based on the 1976 Water Use Survey.
7. An average consumption of 5.2% (Tate, 1980) was assumed for the mining operation in the Liard Basin.
8. Withdrawal for mining in the Slave Lake Basin was based on the annual reports of the mines. Consumptive use was reported by two mines. The third was calculated by using a consumption figure of 12.6% (Tate, 1980).
9. Withdrawal for mining in the Great Bear Lake Basin was based on the annual reports of the mines. Consumptive use was calculated by using an index of 12.6% (Tate, 1980).

Notes to Table 80 Continued

Sources:

A) Alberta withdrawal and consumption patterns were estimated by preparing a chart for each sub-basin as follows:

- All plants licensed and authorized to withdraw surface water by Alberta Environment were grouped according to SIC classification. Licensed withdrawal was listed. This was multiplied by a consumption index for each industrial classification (Tate, 1980) to give approximate consumption.

- The number of employees of each licensed plant (Alberta Economic Development, 1979) was multiplied by a withdrawal/employee index (as calculated by Tate, 1980) for Alberta to estimate withdrawal. The withdrawal figure was multiplied by Tate's consumption index to give an estimate of consumption.

- The withdrawal and consumption as reported by Alberta Environment (1979) on a computer printout prepared as a result of a 1976 questionnaire survey were used.

These three sets of withdrawal and consumption figures were compared and a set of withdrawal and consumption figures was selected to best represent the withdrawal and consumption pattern.

B) The Government of British Columbia provided water licence data for the Peace and Liard River Basins. However, there were no current licences for industrial use.

C) Northwest Territories data are based on the following:

- Licensed water withdrawal
- Withdrawal and consumption, as reported in the annual reports of the various mines
- Tate's 1980 consumption index

These figures were compared and a set of figures was selected to represent the withdrawal and consumption pattern. It should be noted that only licensed water use was included. In the NWT, there are hundreds of authorizations.

Arctic Ocean Drainage

Industrial water use in the Arctic Ocean drainage region is almost totally confined to resource industries associated with petroleum, minerals, and forest products. A summary of present water withdrawal and consumption estimates is contained in Table 80.

Uses are highest in the Athabasca River basin, where 80 to 90 percent of industrial water withdrawn is presently used in the petroleum, coal, and chemical products category. The development of the Athabasca Oil Sands over the past few decades has reached production stages and there is a clear indication that use of water from the Athabasca River drainage will increase substantially for this purpose. At present two plants (Suncor and Syncrude) are in operation, with a third (Alsands) awaiting approval by the provincial government. Alsands may not be in operation prior to 1987, and the next project (Canstar) could follow by three years. A summary of present oil recovery volumes and water requirements is contained in Table 81. From this it can be estimated that present technology requires withdrawals of just over two cubic metres of water per barrel of oil produced, some of which is returned to surface drainage systems. However, recycling procedures at Syncrude have recently reduced their rate of water withdrawal, and very little waste water is discharged. The Alsands proposal suggests a further reduction of this amount to about 0.55 m^3 per barrel of oil produced after the third year of operation. This would depend upon the success of recycling technology.

TABLE 81. WATER REQUIREMENTS FOR OIL SANDS DEVELOPMENTS
(PRCF; ALTA ENV.; ESSO RESOURCES CANADA, ALSANDS PROJECT GROUP)

PLANT	OIL RECOVERY VOLUMES B/D	OIL RECOVERY VOLUMES M^3/D	FRESH WATER REQUIREMENTS M^3/D	FRESH WATER REQUIREMENTS M^3/S	RATIO* M^3/B
SUNCOR (1)	42 500	6 800	84 000	0.97	1.98
SYNCRUDE (2)	49 000	7 800	125 000	1.44	2.55
ALSANDS (3)	140 000	22 200	78 000	0.90	0.55
COLD LAKE	140 000	22 200	93 000	1.07	0.66

NOTES: (1) FIGURES ARE FOR 1979. THERE IS NO RECYCLING OF WATER.

(2) FIGURES ARE FOR 1979. IN 1980, SYNCRUDE COMMENCED RECYCLING OPERATIONS.

(3) FIGURES ARE THOSE PROJECTED FOR THREE YEARS AFTER PLANT START-UP, WHEN WATER RECYCLE WILL BE ESTABLISHED.

* WATER TO OIL

A 1975 study of oil sands development scenarios indicates a reduced water demand after about five years operation (Stanley Associates, 1975). This study examined the total supply requirements of up to 13 plants of 100,000 bbl/day capacity and suggested a maximum total demand of about 14 m^3/s. However, the slowdown in development seen in recent years, and the likely phasing out of early plants by the time later plants are developed make this scenario unlikely. If production in the

Athabasca Oil Sands reaches 1,000,000 barrels per day, water requirements would become between about 0.5 and 1.0 million cubic metres per day, or a flow of between six and twelve m^3/s. An estimate by Alberta Environment (1974b) was a consumptive use of about 10 m^3/s from the Athabasca River for production of one million barrels per day.

Oil sands mining and extraction involve the handling of both surface and ground waters. To facilitate the mining operations, near-surface aquifers must be depressurized. The disposal of this water, which is saline, may be either to local surface drainage or to the ponds used to store mine tailings. For example, the Alsands project proposes to pump mine water at a rate of about 0.2 m^3/s (Alsands Project Group, 1978). This water, with a chloride level of about 2 000 ppm, would be discharged to a tributary of the Athabasca River for one to two years, then to the tailings pond.

Water used in oil extraction processes is obtained initially from surface supplies, then discharged to tailings ponds in a mixture with sand, bitumen, and chemicals used in the processing. In some cases, a small fraction of clarified water is decanted to the Athabasca River. The tailings ponds lose some water to evaporation, and some to seepage, but become the main source of process water through recycling. The effects on the quality of the Athabasca River are not presently considered to be significant, except locally.

Future expansions in the Fort McMurray area will result in increased retention of large volumes of very poor quality water in ponds, as well as increased discharges of poor quality water to the river. The trend, however, appears to be to reduce the fraction of process water discharged to surface drainage, and to retain mine dewatering effluent. The major direct sources of contaminated discharge in the future could be the wastes from local surface drainage and ancillary operations.

The integrity of retention pond construction and methods used to control seepage appear at present to be adequate. The addition of several new plants, however, could increase the significance of seepage losses to the Athabasca River, and also the possibility of a catastrophic discharge of very poor quality water due to dyke failure.

A number of gas plants in this basin also use water, making up the balance of the total for this industrial category in Table 80.

In the mining sector, approximately 1500 m^3/d is used in the coal mining industry, about half of which is consumed. About 800 m^3/d is licensed for use in the production of concrete, mainly in the Fort McMurray area.

In the forest products industry, 86 000 m^3/d is presently withdrawn, 4000 m^3/d of which is consumed. The principal operation is a pulpmill at Hinton. Future growth in this sector will include a pulpmill being constructed near Whitecourt. Although the Hinton pulpmill discharge effluent locally affects the water quality of the Athabasca River, these effects are not constraining on other uses downstream.

In the Peace River basin, the forest products sector presently dominates the use of water by industry (Table 80). Water is used at a number of stages in the pulp manufacturing process. Although only 3.8 percent consumption rate is indicated nationally, the estimate for this basin is 25 percent (MacLaren, 1980). A mill located south of Grande Prairie on the Wapiti River has been the subject of criticism by downstream users concerned about water quality effects, notably at Peace River. A recent report by Reynoldson and Hamilton (1981) describes toxic effects of effluent from this mill on organisms in the river.

In Alberta some of the largest remaining uncommitted timber lands in the province are located in this basin (Alberta Environment, 1981c). It is thought that a new pulpmill of about 400 tons/day to support development in the Clear Hills area could be located near the Peace River. In the longer term, two additional mills totalling about 900 tons/day capacity could be needed elsewhere in the basin. A water requirement of 180 m^3/ton is estimated (Alberta Environment, 1981c), which would require supplies of 0.8 m^3/s in the near future, and an additional 1.9 m^3/s in the far future.

At present the petroleum industry requires about 12 000 m^3/d, over 80 percent of which is consumed. Development of the Peace River Oil Sands could substantially increase these amounts. These oil sands contain an estimated 75 billion barrels of crude bitumen, and evaluations of recovery processes are being conducted near Peace River by Shell Canada. Gulf Canada is also evaluating recovery in the Wabasca Oil Sands area.

In the Shell Canada case, three estimates of water requirements have been made which range from 1.2 m^3/s to 2.0 m^3/s for a plant capacity of 150 000 barrels per day. If the two developments are considered to be similar, up to 4.0 m^3/s could be required from the Peace River, 97 percent of which could be consumed (Alberta Environment, 1981c).

The possibility of development of relatively low grade iron ore deposits has been considered in the Clear Hills area. A water requirement of 1.5 m^3/s has been suggested, which would increase slightly in the unlikely event that a steel plant were also located in the basin.

Other speculative developments in the Peace River basin include expansion of gas processing plants and refinery facilities using oil sands products.

Water presently used in the non-metallic mining sector (Table 80) is for concrete production at Grande Prairie.

In the Slave/Mackenzie basin the mines and quarries sector (Table 80) constitutes the greatest water user in the industrial category. On the Flat River, which drains to the Liard River, a tungsten mine withdraws 4000 m^3/d, a new base metal mine is being developed on Prairie Creek, while mining operations near Great Slave Lake withdraw almost 25 000 m^3/d, and silver mining near Great Bear Lake takes nearly 2 000 m^3/d. Consumption rates are highest in the Great Slave operations. Mining is expected to expand if transportation corridors are developed for purposes of the oil and gas industry (Falk et al, 1974).

The only present petroleum sector use is at the Norman Wells oil fields, where a ten-fold expansion of production is expected in the near future. Virtually all of this increase in production will be transported via pipeline to refineries in Alberta. Expansion is tied to a major oil field water injection program, and water withdrawals are expected to increase from 3000 m^3/d to about 9500 m^3/d. Water flooding and oil pumping will take place from artificial islands constructed in the Mackenzie River. About one-third of the water withdrawn will be returned clean to the river, the remainder being lost in the ground. The refinery at Norman Wells will not be expanded and will continue to use close to its licensed amount of 2300 m^3/d.

Two uranium mines, Eldorado Nuclear Uranium at Uranium City and Amok at Cluff Lake, are licensed to withdraw 0.18 m^3/s and 0.02 m^3/s respectively, little of which is consumed. Although there are no immediate plans to develop additional mines, a number of significant uranium bodies have been located (e.g., at Meadow Lake), and the Saskatchewan government predicts that world demand for uranium will increase substantially.

In other basins draining to the Arctic Ocean there has been widespread exploration for mineral resources. In the near future, a gold mine is expected to begin operation at Contwoyto Lake, about 300 km northeast of Yellowknife.

Table 82. MUNICIPAL WATER USE, BY BASIN

BASIN	TREATED WATER SUPPLY FROM (PERCENTAGE): LAKE	RIVER	WELL	OTHER	TOTAL FLOW(M^3/S)	TREATED WASTEWATER DISPOSAL TO (PERCENTAGE): LAKE	RIVER	OTHER	TOTAL FLOW (M^3/S)
Oldman	——	98.8	1.0	0.2	1.53	5.3	89.7	5.0	0.78
Bow	1.0	96.0	1.5	1.5	4.75	——	98.4	1.6	4.02
Red Deer	2.3	62.3	31.5	3.9	0.43	1.1	95.2	3.7	0.33
North Saskatchewan	2.8	87.4	8.8	1.0	3.54	1.9	98.0	0.1	3.30
South Saskatchewan	0.5	95.1	4.3	0.1	0.99	——	92.5	7.5	0.70
Saskatchewan	41.3	40.5	18.2	——	0.14	49.0	51.0	——	0.09
Qu'Appelle	43.4	1.8'	12.6	42.2	1.71*	2.8	97.2	——	0.89
Assiniboine	——	68.2	31.8	——	0.62	2.0	98.0	——	0.45
Red/L. Winnipeg	87.7	10.5	1.8	——	3.36	3.2	96.8	——	3.80
Nelson	9.0	91.0	——	——	0.15	3.4	96.6	——	0.10
Churchill	57.6	38.3	4.1	——	0.13	39.6	60.4	——	0.04
Missouri	——	67.9	32.1	——	0.02	——	100.0	——	0.01
Athabasca	10.4	80.5	9.1	——	0.36	2.5	97.5	——	0.13
Peace	38.6	53.1	8.3	——	0.19	3.7	96.3	——	0.14

* INCLUDES SUPPLY FROM BUFFALO POUND LAKE

SOURCE: MUNDAT DATA BASE RETRIEVALS, ENVIRONMENT CANADA

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Table 83. MUNICIPAL WATER USE - FIVE MAJOR CITIES

	MILLION M^3/YR
WINNIPEG (1980)	
TREATED WATER SUPPLY, SHOAL LAKE	97
TREATED WASTEWATER DISPOSAL, RED AND ASSINIBOINE RIVERS	107
CALGARY (1979)	
TREATED WATER SUPPLY, ELBOW AND BOW RIVERS	160
TREATED WASTEWATER DISPOSAL, BOW RIVER	124
EDMONTON (1980)	
TREATED WATER SUPPLY, NORTH SASKATCHEWAN RIVER	100
TREATED WASTEWATER DISPOSAL, NORTH SASKATCHEWAN RIVER	90
REGINA (1980)	
TREATED WATER SUPPLY, BUFFALO POUND LAKE AND WELLS	32
TREATED WASTEWATER DISPOSAL, WASCANA CREEK	26
SASKATOON (1980)	
TREATED WATER SUPPLY, SOUTH SASKATCHEWAN RIVER	42
TREATED WASTEWATER DISPOSAL, SOUTH SASKATCHEWAN RIVER	25

5. MUNICIPAL USE

Each of the population centres in the Study Region withdraws water for local domestic, industrial, and other municipal uses. Although most water for these purposes is drawn from rivers, some withdrawals are from lakes, wells, and other sources. These bodies also receive the wastewater from municipalities, though not all returns are to the sources. A description of procedures followed by municipalities in treating supply and waste waters, and some general statistics are found in Chapter VII.

A summary of municipal water use for each drainage basin is contained in Table 82. It is beyond the scope of this report to attempt to summarize the specific water supply and quality issues for the many smaller communities in the Study Region. Especially in upland areas where communities must rely upon tentative sources, problems can be serious in dry years. Because of their greater impact within specific drainage basins, more detailed information for each of Winnipeg, Saskatoon, Regina, Edmonton, and Calgary are provided below (see also Table 83).

Winnipeg does not withdraw its municipal supply from the Red River, taking it instead by aqueduct from Shoal Lake (Figure 58). In 1980, the city used 97 million m^3 of water (City of Winnipeg). This is expected to more than double by 2030. Existing supplies are adequate to the year 1998 (MacLaren, 1980). For future expansion, alternatives include a second pipeline from Shoal Lake or a pipeline from the Winnipeg River. At present, there is no treatment of Shoal Lake water, which occasionally results in complaints about taste and odour. If treatment becomes necessary, the Winnipeg River alternative is preferred (MacLaren, 1980).

Some local industries in Winnipeg use ground water. No constraints on this source have been identified.

Effluent from Winnipeg is discharged to the Assiniboine and Red Rivers. The present volume in dry weather is about 110 million m^3 per year, with a projected increase by 1990 to about 145 million m^3 per year. The actual volume processed during 1980 was 107 million m^3. Peak flows are about 2.75 times the dry weather flows. Improvements are planned to upgrade secondary treatment capacity to handle twice the average dry weather flow by 1990, with a further expansion needed by 2000 (City of Winnipeg, 1981).

Edmonton withdraws its water for local industrial and domestic use from the North Saskatchewan River. Volumes withdrawn presently are about 100 million m^3 per year (3.2 m^3/s), and are expected to increase to over 300 million m^3 per year by 2006. A projection prepared by the city for the period 1981-2006 is in Table 84.

TABLE 84. CURRENT DEMAND PROJECTIONS FOR THE CITY OF EDMONTON'S WATER SYSTEM (CITY OF EDMONTON, 1981)

YEAR	CITY POPULATION	CITY & SUBURBAN CONSUMERS	AVERAGE WATER DEMAND (M^3/s)
1982	523 300	650 830	4.22
1984	542 900	691 180	4.65
1986	562 500	731 550	5.12
1988	582 100	767 720	5.57
1990	601 700	803 890	6.04
2000	688 150	982 640	8.68
2006	760 200	1 089 100	10.42

Waste water includes some storm runoff and so annually is about equal in volume to present withdrawals. All waste water is given primary treatment, while all dry weather flow is given secondary treatment (about 90 million m^3 per year). Increases in waste flows by the year 2005 will require expansion of existing secondary treatment capacities to about 200 million m^3 per year.

The Bow and Elbow Rivers supply Calgary's water supply. In 1979, 160 million m^3 (5 m^3/s) were withdrawn from two reservoirs with a combined treatment capacity of 1 million m^3/d, which is almost reached by peak daily requirements. An expansion of treatment facilities by 1981 will accommodate peak volumes. Additional expansions to meet larger regional requirements have been evaluated (Alberta Environment, 1980a).

The population growth of all communities to be served has been estimated at 2.5 times present populations, by 2006. Assuming a constant use rate, the 2006 demand will reach 400 million m^3, or about 12.5 m^3/s.

At present, two sewage treatment plants with a total capacity of about 370 000 m^3/d provide primary treatment, with capacity for about 310 000 m^3 per day secondary treatment. In 1979, effluents averaged 340 000 m^3 per day (124 million $m^3/yr.$). As with the supply facilities, an expansion is due during 1981, and others have been proposed to meet future requirements (Alberta Environment, 1980a). Tertiary treatment is expected to be given by 1983.

Regina obtains some of its supply from local ground water, but presently relies on a pipeline from Buffalo Pound Lake (see Figure 53) for about 50-75 percent of its needs. Its present 1980 demand amounts to about 31.5 million m^3/yr, 58 percent of which comes from Buffalo Pound. The nearby city of Moose Jaw also pipes in its water supply from Buffalo Pound Lake.

Through the past 50 years, a variety of alternative sources (wells, creeks, etc.) have been explored (Ball, 1979). With the diversion to Buffalo Pound Lake from Lake Diefenbaker and a secure source of ground water for part of its needs, Regina has thus far not encountered serious supply constraints. By 1978, 29 million m^3 of water were available from ground water sources if required. After treatment for iron, this water has a very good quality.

The capacity of the pumping station at Buffalo Pound is about 50 million m^3/yr, of which about 33 million can be assured for Regina. Water quality is a problem, with taste and odour causing the greatest public complaint. High levels of trihalomethanes have been found in the supply system due to by-products of chlorination, although Saskatchewan Environment state that exceedences of Saskatchewan's water quality objectives are "very infrequent". Concerns have also been expressed about possible (and increasing) contamination by agricultural wastes, including biocides. In early 1981, Regina approved, in principle, the installation of a granulated activated charcoal filtration system at Buffalo Pound Lake for treatment of the water quality problems. However, the province turned down a request for financial assistance for this system. A proposal has also been made for a direct pipeline from Lake Diefenbaker, but no decision had been made by late 1981. The province, PFRA, and the cities of Regina and Moose Jaw are presently undertaking a study of the long-term water supply needs of those cities (Saskatchewan Environment).

Using a high Regina population projection, Ball (1979) estimated an annual water use rate of 37 million m^3/yr by 1996. His estimate of highest average weekly use was 164 thousand m^3/d for the same time frame. From these projections, it is estimated that Regina will begin to experience water shortages by 1992 "...unless water supplies are increased or strict water management policies are brought in..." (Ball, 1979). This is based upon the assumption of a supply of 157 thousand m^3/d, an active storage of 141 thousand m^3/d, and imposition of peak requirements.

Regina disposes of its waste effluent to Wascana Creek, which drains to the Qu'Appelle River. The City presently provides tertiary treatment to reduce nutrient loading to the Qu'Appelle drainage system. Return flows amount to about 26 million m^3/yr. Planning is underway to increase treatment efficiency and capacity to meet future demands. At present there are some combined storm and sanitary sewers, which prevents accurate estimation of consumptive use.

Saskatoon withdraws all of its water from the South Saskatchewan River. In 1979, total withdrawal was about 36 million m^3, which increased in 1980 to about 42 million m^3 (1.3 m^3/s). The City averages about 0.6 m^3/day per capita while the peak usage is about 2.3 times the average (City of Saskatoon). The projected increase in demand is expected to be close to proportional to projected population increase, although some expansion of municipal-industrial demand is foreseen. For example, industries requiring about 6.5 million m^3 per year are expected in the near future. The water demand for the year 1993 calculated strictly from projected population growth is 56 million m^3.

Saskatoon experiences no significant problem with the quality of its supply water, although quantity problems sometime occur in dry periods when demands place a strain on its treatment facilities.

Waste water is also returned to the South Saskatchewan River, amounting to about 25 million m^3 in 1980. Sewage treatment facilities include only primary processing at present, but are expected to be upgraded to secondary treatment within a few years.

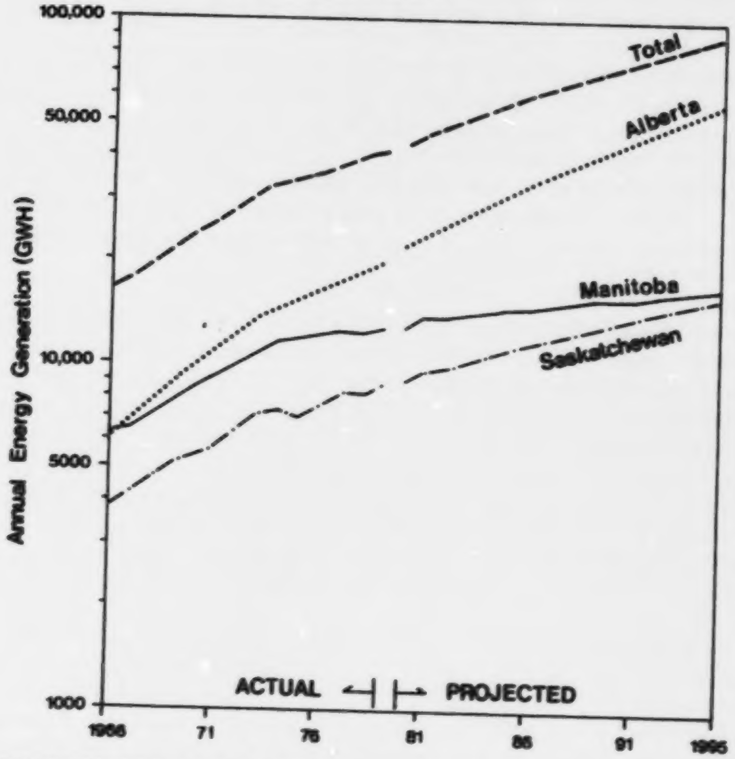
There are no communities with populations over 25 000 in the Arctic Ocean drainage region, so that water withdrawal for each municipality is relatively small. The Athabasca and Peace River basins are by far the most populated, and a summary of total municipal water use for these two basins is given in Table 82. Withdrawals and consumptions are only a fraction of the totals in the more populated basins of the Hudson Bay drainage region.

Water is drawn from a variety of sources, including rivers; lakes, and wells. A number of the more northerly communities must haul water from nearby sources, and some even melt ice and snow (e.g., Tuktoyaktuk). The cold northern climate limits the use of many surface and ground water sources during the winter months. The cold water temperatures also inhibit the assimilation of waste-water discharges in the more northern areas.

Water quantity and quality problems are experienced in a number of communities in the Alberta portion of the region. For example, in the Peace River basin during periods of below normal precipitation, supply problems frequently occur in communities requiring runoff from small drainage basins. During 1980, 12 centres required emergency pumping (Alberta Environment, 1981c). Water quality problems are less widespread, although a significant concern exists at the town of Peace River, where pulp mill discharges upstream have affected the water supply (e.g., during the winter of 1979-80) (Alberta Environment, 1981c).

A few communities in the Peace and Athabasca River basins are anticipating fairly rapid growth in the next few years (e.g., Grande Prairie, Peace River, Fort St. John, and Fort McMurray). Of these, only Grande Prairie and its smaller adjacent communities are expected to experience water supply problems. Fort McMurray, which has grown rapidly and can be expected to expand as oil sands developments increase, has experienced problems of taste and odour although it employs complete conventional water treatment. A study of possible future growth scenarios, including requirements for water supply and sewage treatment facilities, has been prepared by Stanley Associates (1975).

Figure 95. HISTORICAL AND PROJECTED ELECTRIC ENERGY GENERATION IN THE PRAIRIE PROVINCES.

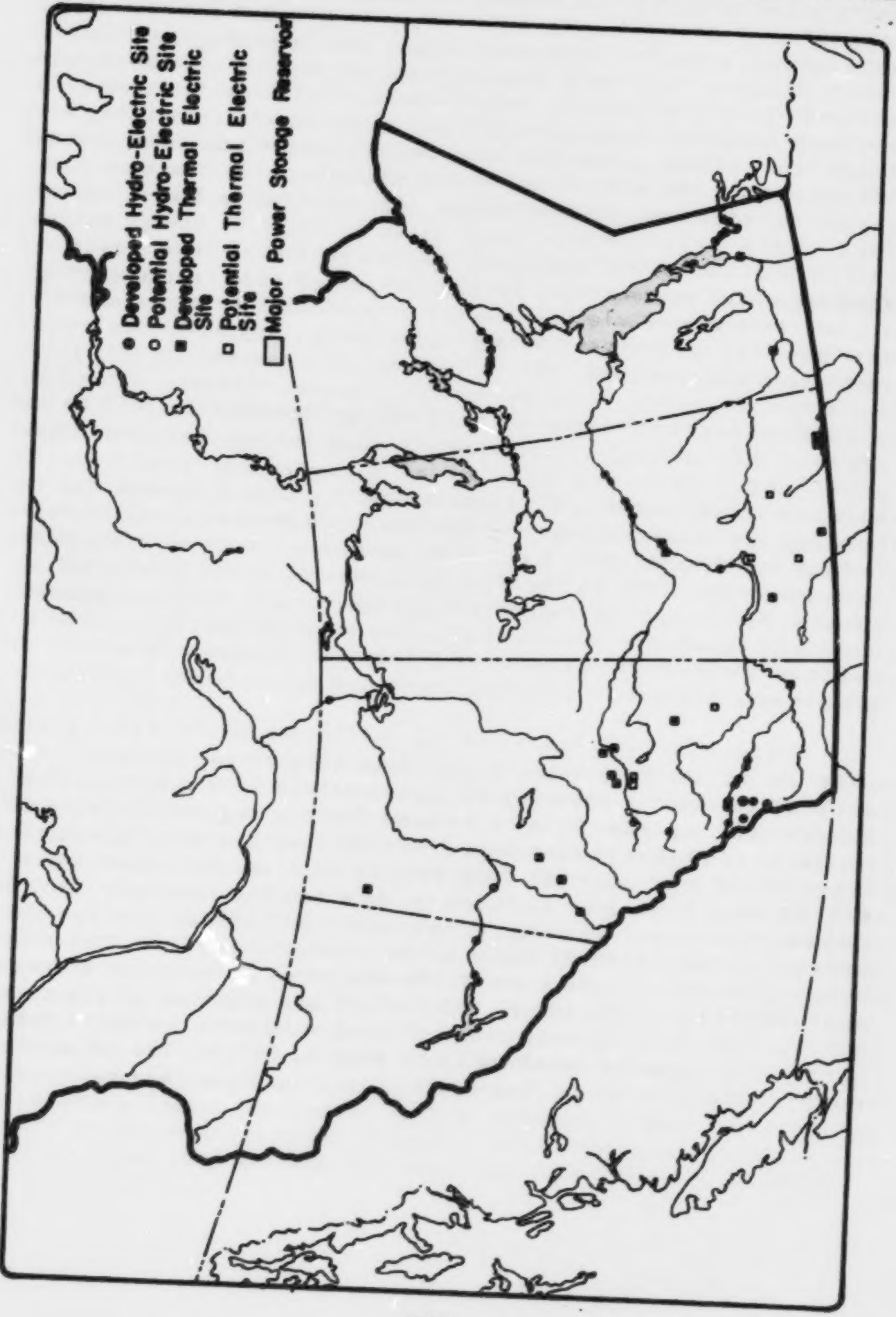


6. ELECTRIC POWER GENERATION

Electric power generation in the Study Region is planned, developed, and regulated on a provincial and territorial basis. No power utility operates in more than one jurisdiction, and except for Alberta, the major utilities are crown corporations of their respective jurisdictions. For this reason, the information in this section is structured according to provinces and territories.

The electric energy generated annually since 1966 in the three prairie provinces is illustrated in Figure 95. The information from 1966 to 1977 was obtained from Statistics Canada reports and that for 1978 and 1979 was estimated from annual reports published by the electric utilities (UNIES, 1980).

Figure 96. DEVELOPED AND POTENTIAL, HYDRO AND THERMAL POWER PLANTS.


● Developed Hydro-Electric Site
○ Potential Hydro-Electric Site
■ Developed Thermal Electric Site
□ Potential Thermal Electric Site
▭ Major Power Storage Reservoir

In the period prior to 1973, growth in demand for electric energy increased at an average rate of approximately 10 percent annually. Consistent with differences in provincial economic and population growths, Alberta showed the largest growth rate at about 12 percent, with Saskatchewan and Manitoba rates at nine percent and eight percent, respectively. Starting in about 1973, a sharp decline in growth rate was experienced, coinciding with large increases in world oil prices and consequent general increases in the cost of many energy sources. At the same time, rapid escalation of development costs and, to a lesser extent, fuel costs have caused sharp rises in electric energy prices. Other factors include high interest rates and costs of environmental protection. During the period 1973 to the present, a real increase in electric energy prices has been experienced in the prairie provinces, whereas previously, a gradual decline in real price was the rule.

Annual growth in electric-energy demand from 1973 to the present has averaged approximately four percent for the prairie provinces. This was made up of a six percent growth rate in Alberta, and rates of slightly less than four percent and two percent in Saskatchewan and Manitoba, respectively. In British Columbia, demand has grown at an average rate of 7.5 percent annually since 1967 on the B.C. Hydro System (B.C. Hydro, 1981a). In the Northwest and Yukon Territories, growth has been sporadic over the past 40 years as isolated supplies for population centres have been developed. For the nation as a whole, the growth rate since 1973 has been about 4.2 percent (EMR, 1979).

Hydro-electric generating facilities in the Study Region portion of the four western provinces (Figure 96) presently have a total generating capacity of approximately 8000 megawatts (MW). The remaining electrical demand in this region (south of 60° N) is met by thermal-electric plants with a total generating capacity of approximately 7000 MW. Of this amount, approximately 275 MW are from gas turbine plants and the remainder is from steam turbine plants which are coal-fired except for approximately 1145 MW fired by natural gas. In 1980, the total hydro-electric production in the Northwest Territories averaged approximately 33 MW (GNWT, 1981) which was supplied by plants on the Snare, Yellowknife, and Taltson Rivers having a total installed capacity of 48 MW (R.L. Walker, 1981). The balance of energy production in the Territories is from diesel plants.

One source of data for the analysis of water use for hydro-electric generation is the Western Electric Power System Study (UNIES, 1979) for the provinces of British Columbia, Alberta, Saskatchewan, and Manitoba. This study provided statistical data on streamflow and reservoir operation for the present relatively isolated operations of the provincial utilities in the region, and for a possible future integrated operation (the Western Power Grid) through improved transmission interconnections crossing provincial boundaries. An integrated system is one alternative for future developments in this region.

Forecasts of future electric energy demand have been revised downward in recent years, mainly in response to the generally unforeseen decline in growth after 1973. Except for Alberta, a forecast of relatively slow growth seems justified by the continuing increase in real cost of electric energy and a general movement toward energy conservation. These factors may be slightly countered by displacement of non-electrical applications.

Projected energy generation for the prairie provinces is also illustrated in Figure 95. The annual rate of increase until 1995 for the three provinces combined is less than seven percent. In British Columbia, the load forecast is for an average annual increase of 5.7 percent over the next ten years (B.C. Hydro, 1981b). Future electricity generation in the territories is contingent upon a major demand developing at some isolated location. "No such occurrence appears in current predictions" (UNIES, 1980).

To meet future growth in electric energy demand, each of the jurisdictions has alternative sources available. In the near future, Alberta is expected to utilize new coal-fired thermal electric plants and, in the longer term, to include relatively large hydro-electric developments on the Peace and Slave Rivers. Saskatchewan is expected to continue with development of both coal-fired thermal electric plants, and hydro-electric plants on the Saskatchewan River. In Manitoba, electric energy demand is less than available dependable supply, so at projected growth rates, there will be no requirement for new generation before the mid-1990s. When new generation is needed, it is expected that additional hydro-electric plants on the Nelson River or on the Churchill Diversion route will be developed (Chapter II.2). In the Study Region portion of British Columbia, future developments will be exclusively hydro-electric, with developments proposed or likely to be proposed for the Peace and Liard Rivers. Although the territories have appreciable potential for hydro-electric development (e.g., 2000 MW in the vicinity of Great Slave Lake (UNIES, 1980)), it is unknown which, if any, of these resources may be developed, or whether power would be imported from Alberta (R.L. Walker, 1981).

Since 1978, interest has increased in the concept of formal arrangements between the three prairie provinces to share electric energy supplies. It has been proposed to strengthen cross-boundary transmission in order to exchange energy and share generation. The UNIES (1979) study indicated that substantial savings in cost of meeting electrical demand in the western provinces could be realized through improved transmission between provinces and a high level of inter-utility cooperation.

A commitment to this system could substantially alter supply development sequences presently projected by individual utilities. It is probable that initially the existing surplus of supply in Manitoba would be utilized to meet demand in all three provinces, since this could be achieved essentially for the cost of the interconnecting transmission. Establishment of interconnections would, in itself, create a further delay in the requirement for new generation by providing the opportunity to take advantage of peak load diversity in the combined systems and reserve capacity sharing. These delays in the need for new generation were shown by the study to amount to a four-year deferral of new generation, and with the reduced demand growth rate now considered probable, a further deferral could be realized. Using demand growth rates in Figure 95, it was estimated that existing and committed generation facilities, plus diversity exchange agreements, could adequately meet demand in the three prairie provinces until approximately 1990 (UNIES, 1980). These estimates are not entirely consistent with those of the several utilities. For example, Saskatchewan estimates a two-year, rather than a four-year, deferral (Saskatchewan Power Corporation).

In the analysis which follows (UNIES, 1980), it is assumed that electrical demand in the long term will be met by full development of the feasible hydro-electric sources plus additional thermal generation to make up remaining demand. The potential and developed average hydro power capabilities of the major river systems in the Study Region are contained in Table 85. The locations of developed and potential electric generating plants are contained in Figure 96.

TABLE 85

POTENTIAL AND DEVELOPED HYDRO-ELECTRIC POWER

(UNIES, 1980)

River	BRITISH COLUMBIA			ALBERTA			SASKATCHEWAN			MANITOBA			TOTAL		
	POTENTIAL	DEVELOPED		POTENTIAL	DEVELOPED		POTENTIAL	DEVELOPED		POTENTIAL	DEVELOPED		POTENTIAL	DEVELOPED	
	Average Power MW	Average Power MW	Installed Capacity MW	Average Power MW	Average Power MW	Installed Capacity MW	Average Power MW	Average Power MW	Installed Capacity MW	Average Power MW	Average Power MW	Installed Capacity MW	Average Power MW	Average Power MW	Installed Capacity MW
Athabasca	—	—	—	1820	Minor	Minor	—	—	—	—	—	—	1820	—	—
Churchill	—	—	—	—	—	—	270	70	90	80	—	—	350	70	90
Peace	2760	1880	3100	2970	—	—	—	—	—	—	—	—	5730	1880	3100
Liard	2900	—	—	—	—	—	—	—	—	—	—	—	2900	—	—
Slave	—	—	—	1120	—	—	—	—	—	—	—	—	1120	—	—
N. Sask.	—	—	—	1190	100	460	180	—	—	—	—	—	1370	100	460
S. Sask.	—	—	—	380	110	330	250	100	190	—	—	—	630	210	520
Sask.	—	—	—	—	—	—	460	120	280	220	220	470	680	340	750
Winnipeg	—	—	—	—	—	—	—	—	—	460	460	560	460	460	560
Burntwood	—	—	—	—	—	—	—	—	—	480	—	—	480	—	—
Nelson	—	—	—	—	—	—	—	—	—	4710	1720	2800	4710	1720	2800
TOTAL	5660	1880	3100	7480	210	790	1160	290	560	5950	2400	3630	20250	4780	8080

A move toward the interconnected grid would combine systems supplied in Alberta and Saskatchewan, mainly from thermal electric sources, with Manitoba's predominantly hydro-electric supplied system. The most economic utilization of these interconnected supplies would be an operation maximizing generation from hydro-electric plants, thus minimizing fuel consumption by the thermal electric plants. A change to this operation would require fairly specific changes to the pattern of generation by both hydro-electric and thermal electric plants.

Hydro-electric plants would no longer be required to retain a large volume of water in storage in anticipation of low streamflow conditions. They would rely instead on the ability of the thermal electric plants to increase energy output during dry periods. In general terms, this change from the present isolated operation of the hydro-electric supplies would result in a reduction in the average reservoir levels, reduction in the frequency of flood discharge from reservoirs, and reduction in minimum discharge from reservoirs.

The impact on thermal electric plants would be a slight reduction in their average generation, operation at a low capacity factor during high streamflow periods, and continuous operation at near full capacity during periods of low streamflow. Waste heat production, and hence cooling water use, are directly proportional to generation (UNIES, 1980).

It is important to note that the description above is dependent upon the acceptance of the Western Power Grid. In the provincial summaries which follow, alternatives to that are inherent in projections provided by the separate utilities. A discussion of water requirements and effects of typical thermal and hydro plant operations is contained in Chapter VII. Those characteristics can be generally applied to each of the plants identified below.

Manitoba

In Manitoba, power generation and distribution are the responsibility of Manitoba Hydro, a provincial crown corporation, and Winnipeg Hydro, owned by the City of Winnipeg. The latter serves a portion of Winnipeg, while Manitoba Hydro serves the rest of the province. Agreements exist between the two for the operation of an integrated system.

The total winter generating capacity of Manitoba Hydro's operations in mid-1980 was 3900 MW, 3500 MW of which was from hydro, and 370 MW from thermal plants. The balance was diesel-

TABLE 86. ELECTRIC GENERATING STATIONS IN MANITOBA - 1980

STATIONS - HYDRO	LOCATION	WINTER CAPACITY (MW)	PERCENT OF ENERGY GENERATED 1979/80
Great Falls	Winnipeg River	132	14.2
Seven Sisters	Winnipeg River	150	
Pine Falls	Winnipeg River	82	
McArthur Falls	Winnipeg River	56	
Grand Rapids	Saskatchewan River	472	6.3
Kelsey	Nelson River	224	8.6
Kettle	Nelson River	1 272	34.4
Jenpeg	Nelson River	126	3.1
Long Spruce	Nelson River	980	27.6
Laurie River (2)	Laurie River	10	5.3
Point du Bois	Winnipeg River	72	
Slave Falls	Winnipeg River	68	
		3 644	95.5
STATIONS - THERMAL			
Brandon	Brandon East	237	0.5
Selkirk	Selkirk	132	
Other (diesel)		54	
		423	
TOTAL GENERATING CAPACITY (1980)		4 067	
MANITOBA FIRM PEAK DEMAND (1980)		2 519	
FUTURE - HYDRO			
Whitemud[1]	Nelson River	240	
Red Rock[1]	Nelson River	340	
Bladder[1]	Nelson River	540	
Birthday Rapids	Nelson River	540	
Gull Rapids	Nelson River	510	
Limestone	Nelson River	1 200	
Conawapa	Nelson River	1 270	
Gillam Island	Nelson River	900	
Kelsey Extension	Nelson River	240	
Notigi	Burntwood River	100	
Wuskwatim	Burntwood River	280	
Manasan	Burntwood River	200	
First Rapids	Burntwood River	170	
Granville	Churchill River	150	
Bloodstone	Churchill River	100	

1. IF BLADDER IS SELECTED FOR DEVELOPMENT, WHITEMUD AND RED ROCK WILL NOT BE DEVELOPED, AND VICE VERSA.

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generated. Winnipeg Hydro's capacity at that time was 140 MW from hydro plants (Manitoba Hydro, 1980).

Generating stations in operation in 1980 are listed in Table 86. In the southern part of the province, there exist six hydro plants on the Winnipeg River (Manitoba Hydro, four; Winnipeg Hydro, two), and two thermal plants (Brandon and Selkirk). The thermal plants are used for peaking and to firm up energy requirements during low flow years. In 1979/80, a good year for water supply to hydro stations, they supplied only 0.5 percent of total generation. In 1976/77, a poor year for water supply, 11 percent came from the thermal plants.

In the northern part of the province, massive power developments associated with the diversion of the Churchill River into the Nelson River (Chapter II.2), and control of Lake Winnipeg, have produced four operational stations on the Nelson River. Two small plants on the Laurie River have also been in operation since the 1950s to serve local mining needs. A major hydro station also exists on the Saskatchewan River at Grand Rapids.

The Churchill-Nelson diversion presently provides a transfer of 850 m^3/s to the Burntwood-Nelson system. Manitoba Hydro is examining the possibility of requesting additional transfer during periods of high supply.

The priorities given for future hydro developments in Manitoba depend upon whether or not the Western Power Grid is adopted. The order of likely development is given in the following:

with power grid:
1. Limestone (1988)
2. Conawapa (1991)
3. Burntwood sites (mid-1990s)

with no power grid:
1. Limestone (1992)
2. Burntwood sites (mid-1990s)

Development of the Burntwood sites could result in flooding problems, which would be contrary to an agreement with native groups. As an alternative, the Bladder and Gull sites could be developed first. Future hydro expansion will not require additional major river diversions. Increased flows in the present diversion are, however, a possibility.

Foreseeable power developments in Manitoba do not include nuclear or additional thermal plants. Although a site-location study for a nuclear plant was carried out by Manitoba Hydro (first choice: Winnipeg River), no specific plans for nuclear power development have been proposed.

Table 87. ELECTRIC GENERATING STATIONS IN SASKATCHEWAN - 1980
(SPC, 1981b)

STATIONS - HYDRO	LOCATION	RATED CAPACITY (MW)	PERCENT OF ENERGY GENERATED 1980
Squaw Rapids	Saskatchewan River	280	12.0
Coteau Creek	South Saskatchewan River	187	7.8
		467	19.9
STATIONS - THERMAL			
Boundary Dam	Estevan	874	67.5
Estevan	Estevan	65	4.6
A. L. Cole	Saskatoon	108	L 0.1
Queen Elizabeth	Saskatoon	232	6.8
Poplar River	Coronach	294	0.4
Other (diesel)		115	0.8
		1 688	80.1
TOTAL GENERATING CAPACITY (1980)		2 155	

Note: the hydro stations at Island Falls (107 MW) and near Uranium City are not included above.

FUTURE HYDRO			
Nipawin	Saskatchewan River	250	
Other	Saskatchewan River	600	
FUTURE - THERMAL			
Other	Wood River, Lake Diefenbaker, or Regina	1 200	

L = less than

Saskatchewan

In Saskatchewan, with minor exceptions, all electric power generation is the responsibility of the Saskatchewan Power Corporation (SPC), a provincial crown corporation. All hydro and thermal plant locations are shown in Figure 96. As of early 1981, SPC operated two hydro and five steam plants, having a total capacity of just over 2000 MW (Table 87). In April, 1981, SPC also assumed responsibility for the 90 MW hydro operation at Island Falls, previously licensed to the Hudson Bay Mining and Smelting Company. The Eldorado Nuclear Company operates hydro plants (about 20 MW) near Uranium City, under license. SPC operates that portion of the distribution system that supplies power to the Uranium City townsite.

A new hydro-electric plant at Nipawin on the Saskatchewan River (250 MW) was approved in early 1981. According to SPC

(1981a), additional hydro developments totalling about 600 MW are being considered at Choiceland and The Forks on the Saskatchewan River. Lignite coal-fired thermal sites are being studied at Wood River, Lake Diefenbaker, and Regina for a plant that could eventually total 1200 MW. Consideration of the expansion of the 600 MW Poplar River thermal plant to 1200 MW is a possibility. SPC considers that the smallest economical nuclear plant would be too large for its purposes.

TABLE 88. ELECTRIC GENERATING STATIONS IN ALBERTA - 1980

STATIONS - HYDRO	LOCATION	RATED CAPACITY (MW)
BOW RIVER PLANTS	BOW R. & TRIBUTARIES	325
BRAZEAU	BRAZEAU RIVER	355
BIGHORN	N. SASKATCHEWAN RIVER	120
		800
STATIONS - THERMAL		
SUNDANCE	LAKE WABAMUN	2 060
WABAMUN	LAKE WABAMUN	590
BATTLE RIVER	FORESTBURG	760
CLOVER BAR	EDMONTON	685
ROSSDALE	EDMONTON	375
H. R. MILNER	GRANDE CACHE	140
MEDICINE HAT	MEDICINE HAT	165
RAINBOW	RAINBOW LAKE	70
STURGEON	VALLEYVIEW	20
SIMONETTE	S.E. OF GRANDE PRAIRIE	20
		4 885
TOTAL GENERATING CAPACITY (1980)		5 685
FUTURE HYDRO		
DUNVEGAN (PROPOSED)	PEACE RIVER	1 000 (1990's)
OTHER	SLAVE RIVER	1 800
FUTURE - THERMAL		
KEEPHILLS (APPROVED)	KEEPHILLS	375 (1983) 375 (1984)
SHEERNESS (APPROVED)	SHEERNESS	375 (1985) 375 (1986)
KEEPHILLS (PROPOSED)	KEEPHILLS	375 (1985) 375 (1986)
GENESEE (APPROVED)	GENESEE	375 (1987) 375 (1988)

Alberta

In Alberta, electric power utilities include two private companies, TransAlta Utilities (formerly Calgary Power and referred to as such in this report) and Alberta Power, and municipal utilities owned by Edmonton, Calgary, Medicine Hat, Red Deer, and Lethbridge. These utilities, between them, presently operate ten thermal plants, which have a total capacity of 4900 MW. In addition, Calgary Power operates 13 hydro plants, 11 located in the headwaters of the Bow River and two in the headwaters of the North Saskatchewan River. The capacity of these totals approximately 800 MW (Calgary Power, 1980), while the average developed power totals 203 MW (UNIES, 1980). Summaries and locations of all the above are contained in Table 88 and Figure 96 respectively.

The Energy Resources Conservation Board (ERCB) advises the Government of Alberta on all matters related to energy developments in the province. The ERCB (1978a) has projected that thermal power generation will continue to be the primary source of electric energy, and that the province's large coal reserves will increasingly be employed, whereas the use of natural gas for this purpose will remain relatively level (Table 89). The demand for oil is entirely related to on-site generation at oil sands plants.

TABLE 89. ENERGY RESOURCES REQUIRED TO MEET ELECTRIC ENERGY DEMANDS IN ALBERTA (ERCB, 1978)

	1977	1991	2006
COAL (10^6 TONNES)	8.5	23.0	48.4
GAS ($10^6 M^3$)	1200	700	850
HYDRO (GWH)	1530	9800	14 000
OIL ($10^3 M^3$)	80	1130	2960

GWH - GIGAWATT HOURS

A summary of proposed new power developments in Alberta is also contained in Table 88, including the names of drainage basins affected. In addition, 11 other possible thermal plant locations have been identified by the Electric Utility Planning Council (EUPC, 1981) which represents Alberta's power producers and distributors. None of these has yet been proposed to the ERCB.

As of early 1981, the following thermal power developments had received approval: the first two units of the Genesee plant (750 MW) of Edmonton Power, two units of Calgary Power's Keephills plant (totalling 750 MW), and two units of the Sheerness plant of Calgary Power and Alberta Power (totalling 750 MW). Application had also been made by Calgary Power for two further 400 MW additions to its Keephills operation. Water requirements for each of the above are described in the supply/demand analyses for each basin in Chapter IV.

No hydro-electric plants presently exist in the Alberta portion of the Peace River basin, although several potential sites exist. UNIES (1980) estimates an average developable power of 2970 MW. While hydro development is becoming increasingly attractive from an economic point of view, difficult foundation conditions make suitable sites difficult to find.

Proposals had been received in mid-1980 by Alberta Utilities and Telephones from two sources for the development of a hydro plant at the Dunvegan site on the Peace River. Calgary Power, and a consortium of Alberta Power, Edmonton Power, and the City of Medicine Hat, each proposed a 41 metre high dam and a plant capable of about 1000 MW production. The proposed reservoir would cover about 3100 ha over a 130 km length of the river. Commissioning of units for this development is expected no earlier than 1990 (EUPC, 1981).

UNIES (1980), in describing future hydro developments, considers that new sites on the Peace River would not significantly alter streamflow patterns downstream because of the existing upstream regulation and the lack of significant new reservoir development.

The Alberta Government is investigating possibilities for a hydro plant on the Slave River, with a potential generating capacity of about 1800 MW. A study that is "...examining the technical and economic feasibility in light of economic, environmental and social impacts..." is being conducted, and is scheduled for completion in 1982 (EUPC, 1981). The proposed date for commissioning the first unit is 1995.

British Columbia

In British Columbia hydro-electric power is primarily produced by the B.C. Hydro and Power Authority. In the Study Region, two plants are presently in operation, both of which benefit from the storage of water in Williston Lake (live storage - 41 million dam^3), formed behind the W.A.C. Bennett Dam (Figure 96). The Gordon M. Shrum station with a capacity of 2416 MW is followed closely downstream by the Peace Canyon station which has a 700 MW capacity. A third major installation is proposed by B.C. Hydro at "Site C" near Fort St. John. The new dam would establish a 51.2 m head, enabling a plant capacity of 900 MW (B.C. Hydro, 1981a). A public hearing by the Public Utilities Commission (B.C.) for the purpose of hearing interventions concerning this proposal was scheduled for the autumn of 1981.

An additional potential site on the Peace River has been identified close to the Alberta border. This possibility has been set aside for the present by B.C. Hydro.

A number of alternative proposals for the development of hydro potential of the Liard River are being considered by B.C. Hydro. One potential reservoir on the Liard River could regulate flows for two hydro-electric plants utilizing approximately 300 metres of head and with a combined generating capacity planned at between 4000 and 5000 MW. Probable development time for these plants is not known, but would not likely be earlier than the mid 1990s.

Northwest and Yukon Territories

In the Northwest and Yukon Territories, electric power is produced primarily by the Northern Canada Power Commission, a federal crown corporation. The existing hydro-electric power plants and possible future development have already been described. For a more detailed summary see NCPC (1980).

7. RECREATION USE

Throughout the Study Region, governments and the private sector have established areas for recreation and for the development and protection of components of the environment important to recreation. In most cases, water resources are important components of these areas.

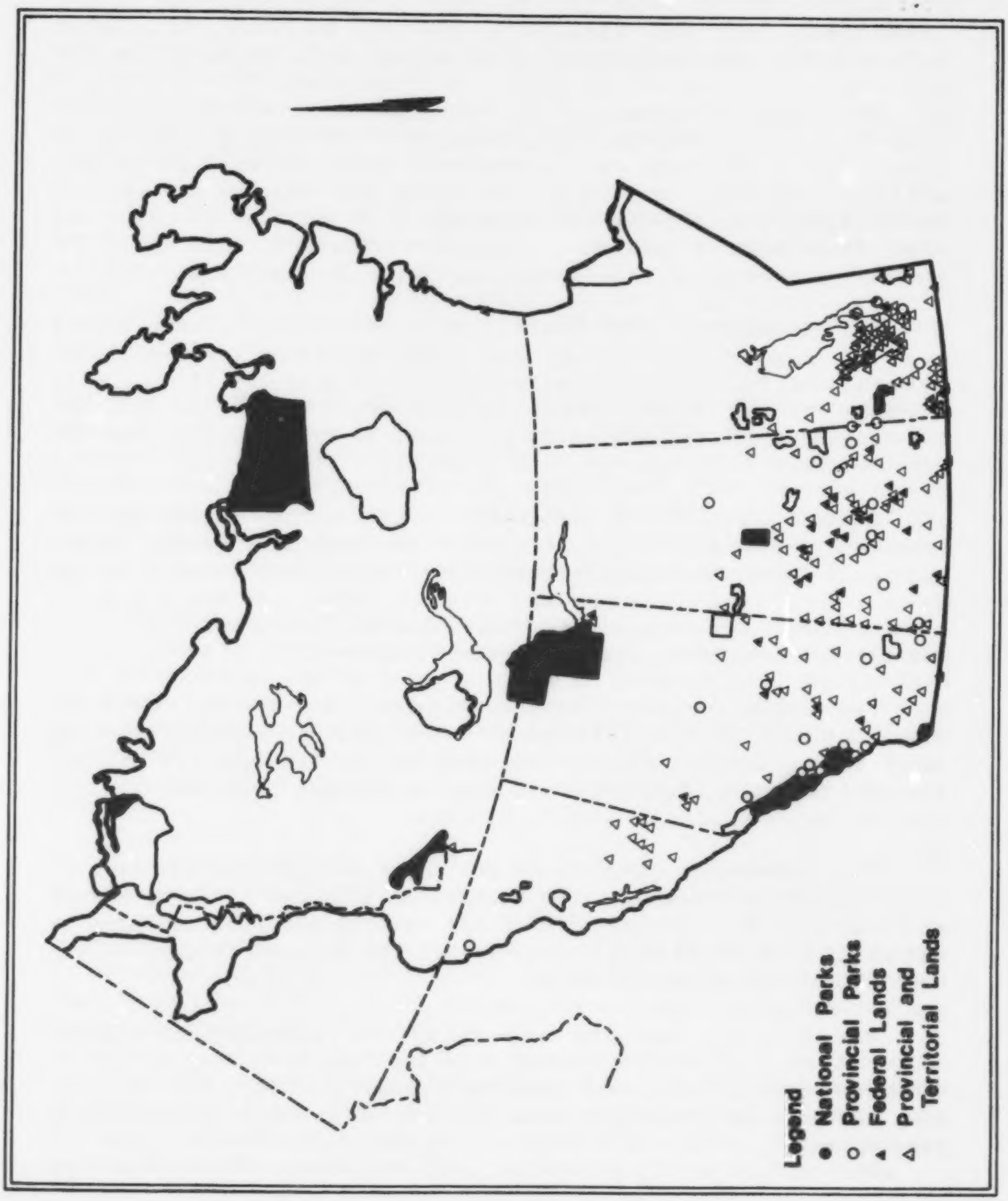
The locations of federal and provincial parks in this region are contained in Figure 97. Also shown are locations of wildlife preservation areas established by provincial, territorial, and federal governments. In addition, several levels of government have established numerous recreation sites, campgrounds, games reserves, ecological sites, and other lands suitable for recreation or preservation.

Some private companies have also provided recreational opportunity as a by-product of reservoirs established for their water supply. The largest privately funded program in the region is that of Ducks Unlimited. Over 1700 individual projects have been implemented (almost 1400 in the Study Region), involving the development of almost three million acres (1.2 million ha), and the construction of many dams and other works suitable for the preservation and enhancement of wetlands for waterfowl (Ducks Unlimited, 1981). DU has also developed an extensive educational and lobbying program to entrain the cooperation of sometimes competing interests, such as the agriculture industry.

In Manitoba, 44 projects were developed in 1980 involving 35,300 acres (14 300 ha), including completion of a large project at Summerberry Marshes near The Pas. In the Assiniboine River basin near Griswold, a project involving 2700 acres (1100 ha) is being constructed which also provides a reduction in flood threats to local municipalities. Ducks Unlimited is also involved with the Manitoba government in developing multi-use type wetland areas (e.g., the Delta Marsh on the south shore of Lake Manitoba).

In Saskatchewan, the largest DU project is the Cumberland Marsh complex involving 320,000 acres (130 000 ha) in the Saskatchewan River delta. There were 31 ongoing projects in Saskatchewan in 1980, totalling 16 800 acres (6 800 ha). A project at Yorkton Creek Marsh, also involving the Saskatchewan government, will eliminate agricultural flooding, improve 12 000 acres (5000 ha), and provide 280 shoreline kilometres of waterfowl habitat when completed.

Figure 97. LOCATIONS OF NATIONAL AND PROVINCIAL PARKS, AND OTHER WILDLIFE AREAS.


Legend
● National Parks
○ Provincial Parks
▲ Federal Lands
△ Provincial and Territorial Lands

In 1980, Ducks Unlimited was involved in a total of 54 projects in Alberta involving 6,400 acres (2600 ha), and adding 210 shoreline kilometres of new nesting habitat. An agreement was also reached with the Western Irrigation District on the 1,500 acre (610 ha) Langdon Reservoir Project. Figure 28 indicates the 1980 projects of Ducks Unlimited in the prairies.

The eastern slopes of the Rocky Mountains attract tourists from around the world, in all seasons. The natural setting is ideal for a variety of recreational interests such as skiing, hiking, angling, and other pursuits that rely on the natural environment, including the waterways. In addition to those who come from across Canada and other countries, this region is heavily used by Albertans, whose population is rapidly growing.

The mountains and foothills contain four national parks, over 10 provincial parks, and several other types of lands classified for recreational or protection purposes (Figure 97). A major recent development is Kananaskis Country, a 5200 km^3 recreation area established by the province of Alberta in the Bow River basin.

Though regarded as important for recreation, waters are not completely protected in these areas. In some parks (e.g., Jasper National Park) water contamination by recreational facilities has been identified (Gummer and Block, 1978). In the Bow River basin, some headwaters in Banff National Park and Kananaskis Country are highly regulated by power dams.

The upper reaches of the Oldman, Red Deer, and North Saskatchewan River systems are not yet regulated, offering natural flow conditions for canoeing and angling. In several areas, the drainage systems form an element of prime wildlife habitat and are heavily used by hunters.

The province of Alberta has zoned portions of the eastern slopes for recreational and protection purposes (Alberta Energy and Natural Resources, 1977). In 1981, a decision was made to establish an ecological reserve in the Kootenay Plains of the upper North Saskatchewan basin.

Because the eastern slopes are a resource-rich region, recreation and environmental organizations have been active in lobbying for additional protection measures (see, for example, the Alberta Wilderness Association Newsletter, a quarterly periodical).

In the region where the foothills give way to the Interior Plains, a number of water control developments have affected, or will affect, the recreational uses of natural water systems. Impoundments and diversions for irrigation in the Oldman River basin, the Dickson Dam under construction upstream of Red Deer, and hydro power dams in the North Saskatchewan River basin serve to change the nature of recreation in this region. A proposed new dam on the Oldman River, and a possible addition to the Bighorn Dam development on the North Saskatchewan, would have additional effects.

In these cases, some recreational opportunities are provided by reservoirs, but some feel that the quality of recreation under altered conditions is diminished (e.g., Eisenhauer and Kolar, 1979). The operation of hydro reservoirs is not always compatible with recreation, which requires relatively steady water levels in summer months.

In central and eastern Alberta, where water management activities generally favour higher priority uses, water-based recreation is scattered and relies heavily on both natural and artificial impoundments. In some cases, like the Bow River, access is becoming more difficult. Lakes in all parts of the province in this drainage region are often affected by algae and weeds, due to enrichment from natural and human sources.

Water quality can also be a problem in the river systems, due to waste discharges and/or low flows. Oxygen values in the Red Deer River can be seriously low in late summer. Wastes from Calgary have been cited as contributing to poor quality for fish in the Bow River. Fish die-offs have occurred in this region on hot summer days during low-flow periods (Paetz, 1981). Low flows in the Oldman River basin also are harmful to fish and fish habitat.

In the southern portion of Alberta and Saskatchewan, in drainage to the Missouri River, diminished water supplies affect recreation in dry years. The Milk River basin, furthermore, is prized by some for its unique natural landscape and biota. Development in this basin, which could affect the water resource, has been the subject of recent concern and debate (Wallis and Wershler, 1979) (see Chapter IV.14).

In the South Saskatchewan River Basin in Saskatchewan, Lake Diefenbaker offers recreational opportunity both at the lake, and to the northeast as a result of a diversion canal. Although some parkland exists around the lake, operation of the Gardiner Dam for hydro development does not ensure stable water levels. The diverted water, via the Saskatoon Southeast Water Supply canal, provides an allocated amount of water for both recreation and wildlife to smaller lakes and reservoirs (see Chapter II.2).

In the drainage of the North Saskatchewan and Churchill Rivers in Saskatchewan, sports fishing is a major industry. The development of northern Saskatchewan has served to increasingly provide new access to water bodies previously not used for recreation. Some areas are protected by park development.

A survey of sports fishing in 1975 (STRR, 1978) indicated that almost 45 percent of total provincial "angler days" were expended in this region. Expenditures for angling in Saskatchewan in 1975 were over $35 million.

Developments of concern to recreationalists in this region include heavy oil projects in the headwaters of the Churchill River near Cold Lake, Alberta, and the perceived threat of acid rain to the Shield Lakes in the north (see Chapter II.4).

Existing and proposed hydro sites along the Saskatchewan River offer only limited effects on recreation locally. The Tobin Lake impoundment has attracted people interested in boating and angling. Regulation of this river is a somewhat contentious issue at present, inasmuch as large waterfowl staging areas in the Cumberland delta and downstream in Manitoba are affected by artificial flow regulation. As mentioned previously, Ducks Unlimited is presently completing a waterfowl habitat enhancement program involving the Cumberland delta, and at the juncture of the Carrot and Saskatchewan Rivers in Manitoba, the management of Saskram Marsh. Controversy involving competing land uses concerning both these projects are described in Chapter IV.7.

In the south-central portion of Saskatchewan, lakes in the Qu'Appelle River valley have become centres of recreational development. Six lakes (Pasqua, Echo, Mission, Katepwa, Crooked, and Round) are part of the main stem of the Qu'Appelle River, and Last Mountain Lake extends northward from the river in its upper region. The reader is referred to a booklet published by the Qu'Appelle Valley Management Board, "Qu'Appelle River System and Operation" (1976), for details about management of the river for recreation and other uses.

A 1975 agreement between Saskatchewan and Canada, under the Canada Water Act, allocated 33.7 million dollars for water control and management development of this system, of which 9.5 million dollars was assigned to the development of tourism and recreation.

Both water supply and quality affect the recreational needs in the main stem lakes. Spring flood control and subsequent flow augmentation from Lake Diefenbaker are important elements of flow regulation. Recreation interests require stable lake levels for cottagers, and there must be sufficient flow to support the quality requirements of game fish. In the previously mentioned 1975 sports fishing survey (STRR, 1978), over 20 percent of the provincial total of angler days occurred in the Qu'Appelle system.

Water quality is a more serious recreational constraint in the main stem lakes of this system. A serious eutrophication problem has been partially reduced by phosphorous removal from Regina's sewage.

The Qu'Appelle valley is expected to become an even more important centre for recreation in the future (Schuster, 1981). A master recreational plan being developed will likely include development incentives, protection of historic sites, interpretive centres, and purchases of lands for recreational development.

The drainage to the Souris River in the southeastern portion of Saskatchewan is in a water-poor region, but does include some lake resorts popular for water-based recreation (e.g., Moose Mountain Provincial Park, and Carlyle Lake). A number of reservoirs and regional parks exist on or near the tributaries to the Souris River. A major problem is due to natural and human enrichment of lakes, promoting undesirable weed and algal growth. In some instances (e.g., Boundary Reservoir) competing water uses have priority over recreation.

Portions of the Souris valley in Saskatchewan are prized for a variety of aesthetic reasons. The stretch downstream of Roche Percee is considered to be unique (SRBSB, 1978).

The Souris River drainage in Manitoba, and the Assiniboine River basin, do not contain any major centres for recreation, outside of Riding Mountain National Park (Figure 97), although numerous small centres exist. Several lakes and reservoirs have been developed for cottage-recreation and sports fishing.

Waterfowl habitat in the wetlands of southeastern Saskatchewan and southwestern Manitoba are important areas of hunting recreation. Major waterfowl staging areas are found at Oak Lake, Plum Lake, Whitewater Lake, and the southern portion of Lake Manitoba (Delta Marsh). In years when marshland waters are warm and levels are low, botulism outbreaks can have serious effects on waterfowl. In the summer of 1981, botulism forced large scale drainage of some wetlands to encourage usage of unaffected waters.

The Delta Marsh location is well known as a centre for research on waterfowl. A concern in this region relates to the varying levels of Lake Manitoba, which are locally affected by diversions of water between the Assiniboine River and Lake Manitoba.

The Red River and Winnipeg River basins also provide a variety of lake and reservoir based recreation. The heaviest recreational fishing in Manitoba is found at the Lockport Dam, in the Red River system (IJC, 1976).

In the Roseau River Basin, recreation is somewhat constrained by low flows and seasonal periods of poor water quality (IJC, 1976). In evaluating Pembina River basin developments, the Manitoba Water Commission (1973) observed that hunting and fishing were popular in the basin but that water-based recreation in general lacked adequate facilities.

Lake Winnipeg provides opportunity for beach recreation though the lake is very turbid in the southern basin and there have been problems with weed growth, algae, and high bacteria levels, as well as with beach losses due to higher lake levels established by controls for power production in the Nelson River basin. Nevertheless, as a large lake close to the major urban area of Winnipeg, it is popular for swimming, boating, and fishing. Also, the Netley and Oak Hammock Marshes north of Winnipeg (which are also vulnerable to the botulism problem) are important waterfowl areas.

The Delta Marsh area of Lake Manitoba has been mentioned. In addition, the northern portions of that lake, as well as waters in the "interlake" region between Lakes Manitoba and Winnipeg and other portions of the drainage basin, are relatively undeveloped, providing a variety of opportunities for recreational use of natural water bodies.

The Nelson River Basin, though heavily developed for hydro power, is not readily accessible for recreation to large numbers of people. The development of power generation in this region, including flow augmentation from the Churchill River (Chapter II.2) has been a concern to environmentalists. As hydro power expansion continues, access to the region will become easier, and recreational use can be expected to increase. The other major concern in this basin relates to the impact of airborne waste products from upwind smelters at Thompson and Flin Flon. Lakes in this region are particularly susceptible to the effects of "acid rain".

Farther north, in the Churchill River basin, the diversion to the Nelson River has had an even more significant environmental effect than in the receiving basin. The control of Southern Indian Lake, and the great reduction in the flow downstream in the Churchill River, are important changes. So far, recreational use has not been a major consideration because of the remoteness of the region. Nevertheless, the quality of recreation available is very high. Canoeing in the historic waterways of both the Churchill and the Nelson is considered by some as a highly desirable yet threatened opportunity (Newberry, 1979b).

Very little information about recreational use and potential is available for other drainage to Hudson Bay, except from environmental assessment studies such as for the Arctic Islands Pipeline Program (Beak Consultants, 1978). Present recreational use is very limited, yet there is a concern that the fragile northern environment should be protected.

The potential for recreational fishing is very high. In the District of Keewatin, 16 large and 37 smaller streams have been identified as good or excellent for fish, with grayling the chief species. In northern Manitoba, eleven major fish species exist, including one of the last remaining brook trout populations. Southeast of the Nelson River Basin, the Hayes River and Gods River are known for their scenic beauty and fishing.

Except for the populated portions of the Peace and Athabasca River basins, access to recreational opportunities in drainage to the Arctic Ocean is very limited. A number of federal, provincial, and territorial parks and wildlife areas are located in this region (Figure 97), as well as other lands established for recreation and/or conservation purposes. Because of the undeveloped nature of much of the area, parks and other special lands emphasize conservation rather than recreation.

In the headwaters of the Athabasca River are found Jasper National Park and a portion of the Willmore Wilderness area, the latter shared with the Peace River basin. While Jasper is the centre for a great variety of formal and informal recreation, the region adjacent to the park, and within the basin as far north as the town of Athabasca and Lesser Slave Lake, provides considerable access for canoeing, hunting, and fishing. Forestry and the oil and gas industry have developed roads, cut-lines, and seismic trails deep into otherwise inaccessible country. This region, including the Willmore area, will likely experience increased recreational pressure in the future.

Except for works being developed on Lesser Slave Lake for flood control, the river system is virtually unregulated. Water quality is generally very good for recreation, though erosion and sedimentation problems have become a concern (see Chapter V.2), and there may be increasing conflicts with mining and forestry development.

In the northern portion of the basin, campgrounds are located along the highway through Fort McMurray. The growing population of that city will continue to increase recreational use of the basin near the oil sands development.

Fish migrations in the upper Athabasca River are important to both the sports and commercial fisheries in Lake Athabasca. For this reason, future developments that would affect water quality and sedimentation in this region could detrimentally affect sports fishing.

The Peace-Athabasca delta, though an important waterfowl staging area, presently provides direct recreational opportunities only for local inhabitants and a small number of visitors. Nevertheless, in addition to its importance as a commercial fishery and a source of subsistence to local peoples, the value of the delta and its ecological assets have been recognized as being important subjects for stewardship considerations (Peace-Athabasca Delta Project Group, 1972).

This delta received considerable attention following the severe consequences of reductions in flow of the Peace River when the Bennett Dam was constructed in 1968 (Chapter VI.3). Recently, Smith (1981) reported that recovery of much of the ecological damage has been substantial.

Recreation in the upper part of the Peace River is based somewhat on the Williston Lake reservoir, behind the Bennett Dam, and on other local lakes and streams. Fishing, camping, boating, and some hunting are popular in the British Columbia side of the basin.

Population growth in this area, as well as in the developing portions of the basin in Alberta, will increase the pressure on water-based recreation. Angling licenses in the Peace Region in Alberta increased by 42 percent between 1972/3 and 1977/8 (Alberta Environment, 1981c). Although over 2000 lakes have been identified in this area, data on recreational fishing is available for only about ten percent, and access is a problem. The Wabasca River basin has been indicated as probably the most significant sport fishing recreational development. The main stem Peace River is not popular for fishing because of its high turbidity, but it is used for boating and some hunting.

The lower portion of the Peace River, and the west side of the Slave River, are situated in Wood Buffalo National Park. Among the important wildlife in this region are the nesting whooping cranes, large buffalo herds, and a colony of white pelicans. The latter use an island in the Slave River, and are a concern of conservationists who consider local hydro development a threat to this population. Hydro development could also pose a flooding threat to the buffalo herds in the park. A recent report (R.L. Walker and Partners, 1981) cites these factors, as well as possible enhanced levels of mercury, intrusion of Arctic lampreys from the north, and flooding of portions of the Peace-Athabasca delta, among potential adverse environmental effects.

Recreation northward in the Mackenzie River basin is quite limited due to its distance from populated areas. As a result, much of the environmental interest relates to conservation.

The presently unregulated Liard River contains a number of important features, including hot springs, rapids, and an endangered species of snail. The possible development of this river by B.C. Hydro has resulted in the commissioning of a number of environmental studies (e.g., R.L. and L. Environmental Services Ltd., 1979) by that utility.

In the lower end of this basin, Nahanni National Park protects a portion of the South Nahanni River basin (Figure 97). The effects of an upstream mineral development on the water quality in this part has been the subject of recent study. Environment Canada is considering requesting more stringent licensing provisions for that development by the N.W.T. Water Board. A more recent base metal development on Prairie Creek, also upstream of the park, has also resulted in a water quality study within the park.

The extensive and complex delta of the Mackenzie River is also a feature that could be very sensitive to upstream development. The annual deposition of sediments is fundamental to the ecology of the delta. Studies are underway by B.C. Hydro to evaluate the possible effects of future hydro development in B.C. (on the Liard River) on this delta, as well as on other environmental features that could be affected by altered thermal and flow regimes (see Chapter VI.4).

The foregoing constitutes a brief picture of the variety of recreational interests and opportunities in this Study Region. Some of the specific issues pertaining to this subject are mentioned, but a more detailed description of multi-use issues is to be found in Chapter IV.2 and VI.2.

8. RENEWABLE RESOURCE UTILIZATION

Forestry

In the eastern slopes region of the Rocky Mountains in Alberta, forestry is the most significant commercial renewable resource use. The effects of this industry on water resources is described in Chapter VII, although not enough is yet known to detail effects for each specific drainage basin. Alberta (AENR, 1977) has established zones for forest and watershed protection, and for commercial forestry operations. Forest management agreements exist for the development of large tracts, all in the Arctic Ocean drainage region. Other forestry operations (under Timber Quota and Timber Permit dispositions) occur in the eastern slopes and adjacent regions, but involve much smaller tracts of land.

Peak flows in streams flowing from large forestry blocks, such as near Hinton in the Athabasca River basin, can be augmented by 15-60 percent (ECA, 1979b). Environment Canada has made a general estimate that yield increases average about 25 percent, and that about 80 m^3/s in total would be added to the Peace and Athabasca Rivers if all major tracts were in full operation on a continuing basis. The accompanying increase in soil erosion is of particular concern in the Clear Hills (Peace River basin), Swan Hills (Athabasca River basin) and east slopes region of the Arctic Ocean drainage.

In the southern basins, less is known about the specific effects of forestry practices on water flows or quality, though studies are underway.

In Saskatchewan, commercial forestry operations are mainly in the Churchill, Saskatchewan, and upper Assiniboine River basins. The direct effects of these operations on streamflow and water quality are not known but are less likely to be of concern than in western Alberta. The same can probably be said for Manitoba, where forestry operations occur primarily in the west-central and southeastern parts of the province. In the Northwest Territories, forests are not a large factor in the economy, although there is considerable productive forest in the Mackenzie River valley.

Fishing

Commercial fishing in Alberta produces about four million fish per annum (about two million less than the sports fishery). The most important commercial fishery is on Lesser Slave Lake (Table 90), while a total of 2400 licenses were issued in 1980 for 120 lakes in all parts of the province. In the Lake Athabasca region, about 230 000 ha of lake area are fished, mainly for walleye and whitefish. In the Lesser Slave Lake region, 34 lakes totalling 220 000 ha are fished. In other parts of Alberta, the industry is less active. In the southern part of the province, all commercial fishing is in artificial impoundments.

TABLE 90. MACKENZIE RIVER BASIN COMMERCIAL FISH PRODUCTION (LENNON, 1981)

	1977-78		1978-79	
LAKE	TONNES	DOLLARS	TONNES	DOLLARS
LAKE ATHABASCA	344	213 095	151	128 687
LESSER SLAVE	275	115 894	349	211 982
LAC LA BICHE	61	40 007	75	61 289
GREAT SLAVE	1 630	1 028 706	1 553	1 314 129
TOTAL	2 310	1 397 702	2 128	1 716 215

Very few environmental problems affect the Alberta fishery. A parasite problem presently affects part of the whitefish population in Lake Athabasca. The disruption of the Peace-Athabasca delta when Peace River flows were reduced affected spawning areas of walleye and goldeye. Although lake level restoration has occurred, works to regulate levels presently block fish migrations northward from the lake. There is also some concern about possible future water quality problems in this region from oil sands developments near Fort McMurray (Smith, 1981).

Decreasing harvests from Lesser Slave Lake are possibly due to increased silt loads, high lake levels, and genetic changes in the fish population. Increasing eutrophication could affect the fishery on Cold Lake.

Commercial fishing in Saskatchewan is also predominantly found in the north. As with Alberta, there has been a recent decline in the industry, with less than 1500 licenses issued in 1978-79 (DNS and STRR, 1981). In that year, catches totalled 2700 tonnes, half that of 1961-62. In 1979-80 the figure increased to 4200 tonnes, for a value of $3.8 million. Although the number of commercial fishermen is decreasing, stocks are increasingly threatened due to a rapidly expanding population of anglers.

This conflict is just one concern of fishery management in the province. Habitat is being threatened by various land use activities and their direct (e.g., dams blocking migration) and indirect (e.g., mercury contamination) effects.

Forty-five percent of commercial catches are whitefish. Though mainly harvested in northern basins, they are also the basis for a fishery in Lake Diefenbaker and in the Qu'Appelle lakes. Management problems include overharvesting and loss of habitat. A description of all species, their role in the provincial commercial fishery, and problems foreseen in their management is contained in a report by Department of Northern Saskatchewan and Saskatchewan Department of Tourism and Renewable Resources (DNS AND STRR, 1981).

Mercury concentrations in the commercial fishery have been a concern, particularly in northern Saskatchewan. A study by DNS (Murray, 1978) on 208 lakes found that fish with concentrations greater than 0.44 ppm occurred in 25 lakes and that 81 lakes had fish with concentrations between 0.25 and 0.44 ppm. Most of the first 25 lakes were located between Reindeer and Cumberland Lakes. The source of mercury in the lakes draining to the Saskatchewan River was primarily industrial, while natural sources were cited for lakes in the Churchill River basin.

Acid rain is a subject of increasing concern in northern Saskatchewan. Lakes in the Canadian Shield region are considered to be threatened by industrial sources in both Alberta and Manitoba. Oil sands developments have already affected the acidity of some Saskatchewan lakes. Liaw and Atton (1980) have identified those lakes in Saskatchewan sensitive to acid rain and have recommended investigation of lakes within 350 miles downwind of Fort McMurray and Cold Lake. They also recommended a target minimum value pH of 6.5 for protection of the fishery resource in that region.

An extensive contamination by mercury has also been reported in the Qu'Appelle River basin (Munro and Gummer, 1980). Elevated concentrations in fish were investigated and the dredging of contaminated sediments in an upstream tributary was suggested as the source.

In Manitoba, Lake Winnipeg, Lake Winnipegosis, and Lake Manitoba have important commercial fisheries. The former is the largest in the province (1400 to 2000 fishermen). Other smaller lakes also have viable commercial fisheries. Southern Indian Lake is an example that is well known because of the substantial changes to its characteristics caused by the Churchill-Nelson diversion (Chapter II.2).

Commercial fishing in the major lakes in Manitoba is not expected to expand in the foreseeable future. The proposed Garrison Diversion Unit (GDU) is considered to be a threat to the fishery because of the possibility of transfer to these lakes of fish species, fish parasites, and fish diseases now found in the Missouri River system. The International Joint Commission (1977) estimated annual losses of $6 million due to the GDU. This would essentially eliminate the fishery.

Effects on the Southern Indian Lake fishery have received initial evaluation. Decreased catches in traditional fishing areas have apparently resulted in a shift in the fishing effort and a higher percentage of poorer quality fish in the catch. Concentrations of mercury increased significantly in the commercial catch following the impoundment of the lake.

Great Slave Lake is the chief area of commercial fishing in the Northwest Territories. Other fisheries for local markets could be developed in the future. However, the industry is not well established in other areas and fluctuates from year to year.

Native Uses

Native peoples in the Study Region are an important component of the commercial fisheries described above, especially in the NWT and the northern areas of the provinces. Domestic fishing is also an important renewable resource use, involving most of the same fisheries, as well as many other smaller lakes.

Subsistence fishing, hunting, and trapping are complex subjects, not well summarized in any literature. Lennon's (1981) report provides a recent summary of available material. These uses are vulnerable to the effects of competing water uses that, in the far north, are not yet of significance. In more southerly locations, competing uses are more significant. A few examples are the previously described events of the Peace-Athabasca delta, the concerns of the Cree of the Churchill River basin about hydro-electric development (Saskatchewan Federation of Indians, 1976), and the also previously described Southern Indian Lake development.

Farther south, native groups are becoming increasingly active in not only subsistence usages, but also other more commercial aspects of water resource use. In addition to commercial fishing, native groups are concerned with agricultural, domestic, and recreational aspects. Specific examples include the Peigan Band in southern Alberta, and the Qu'Appelle Valley Indian Development Authority (QVIDA). Both have strong interests in water management developments in their areas. Again, as an example, the reader is referred to QVIDA (1979), which is a directional plan for natives in the Qu'Appelle River valley. Water resources development and environmental assessment are programs included in the plan.

9. TRANSPORTATION USE

Hudson Bay Drainage Basin

The use of rivers and lakes for transportation within the Hudson Bay drainage region involves about 50 vessels with cumulative gross tonnage of about 9000 tonnes. Of these, 28 are ferries in the three prairie provinces, seven are passenger excursion and cruise vessels, and the remainder are tugs, general cargo ships, and barges. Apart from excursion vessels and ferries, all commercial cargo vessels in this region operate on Lake Winnipeg. Principal cargoes are fish (over 270 tonnes annually), pulpwood, fuel, and silica sand. Only one operator relies on community re-supply and household effects for most of its business. One new vessel service started in 1980, the Wollaston Lake ferry operated by the Saskatchewan Government with a former self-propelled fishing barge.

Lake Winnipeg commercial shipping has experienced a steady decline in general freight traffic over the past decade. New highways to communities such as Norway House have severely cut into the waterborne freight market. Future highway expansion plans include a road to Berens River which would further reduce vessel cargoes, principally lumber. The slack demand situation combined with a normal ice free operating season from May to late October does not provide much prospect for future expansion. Current operators rely on established customers, but all accept a steady annual decline in general cargo tonnages as inevitable.

Water quality is not a factor in water transportation within the Hudson Bay drainage area. Vessel sewage discharge is insignificant and there is little potential for a large spill of oil or other hazardous material because the volumes transported are low.

Low water levels on Lake Winnipeg have been cited by all present operators as being an annual occurrence, normally most acute in the fall when N/NW winds cause as much as a one metre drop in lake levels in the northern basin. This creates problems with offloading, especially on the east shore, as well as limiting vessel cargoes.

The 1980 season was particularly affected due to severe drought conditions in the eastern part of the basin. The Cross Lake Ferry on the Nelson system was unable to run for two weeks due to low water (effectively cutting off the community to all but air shipments). In order to restore ferry service, Manitoba

Hydro had to release water through the Jenpeg hydro project to raise levels. The Split Lake Ferry service was affected by low water from the Kelsey dam site during 1980. In the Red River, water levels are a potential problem for the stretch between Selkirk and Lake Winnipeg. The largest vessel in inland service, the M.V. Lord Selkirk II, operates along this route and just clears some mud flats at times. The federal government operates a continuous dredging service at the mouth of the Red River all season to prevent silt build-up. Only one operator has cited spring high water on the Red River as being a problem.

Generally all of the Lake Winnipeg operators have felt that hydro developments provide more stable lake levels, and that drought situations would hinder navigation even more without the water regulation provided by Manitoba Hydro.

Manitoba presently has six ferries active in the Hudson Bay drainage basin. Of these, three are operated by the provincial government on the Nelson River system, two on Lake Winnipeg, and one on the Assiniboine River near the mouth of the Souris. The Cross Lake ferry was replaced by a road in 1981.

Saskatchewan has fifteen summer cable ferries and two self-propelled ferries, one a year-round bubbler-assisted operation at Buffalo Narrows between Peter Pond Lake and Churchill Lake, and the other the summer ferry at Wollaston Lake. Nine cable ferries operate across the South Saskatchewan River, four across the North Saskatchewan River, and two across the Saskatchewan River. Low water has not presented a major problem at any of the crossings. The cable ferries serve principally to transport agricultural machinery between farms separated by the river.

Many of these ferries are being replaced by bridges. The Saskatchewan Government anticipates having only two or three remaining within six years (this is in marked contrast with the 43 ferries in service in 1921). Regular services across the South Saskatchewan date back to 1871, and the ferry service has played a major role in the province's rural transportation system for over 80 years.

Alberta operates six ferries within the Hudson Bay drainage basin, one across the Bow River, three across the Red Deer River, and two across the North Saskatchewan. Some crossings can experience interruptions to service during years when spring runoff is low, but it is not generally a critical problem. Alberta expects to replace two to three crossings by bridges in the next four years.

The general trend in this drainage region has been for water transport to play an ever decreasing role in the transportation of people and freight in Canada's three prairie provinces. New highways and bridges will gradually replace ferries and established vessel cargo routes. Excursion vessels operate profitably on the Red River, but the large cruise vessel Lord Selkirk II can barely break even with almost 100% load factors, due to increasing operating costs spread over a short season.

Arctic Ocean Drainage Basin

All water transportation within the Arctic Ocean drainage basin takes place in the Mackenzie River system. Within this watershed there are six basic transportation routes (Figure 98):

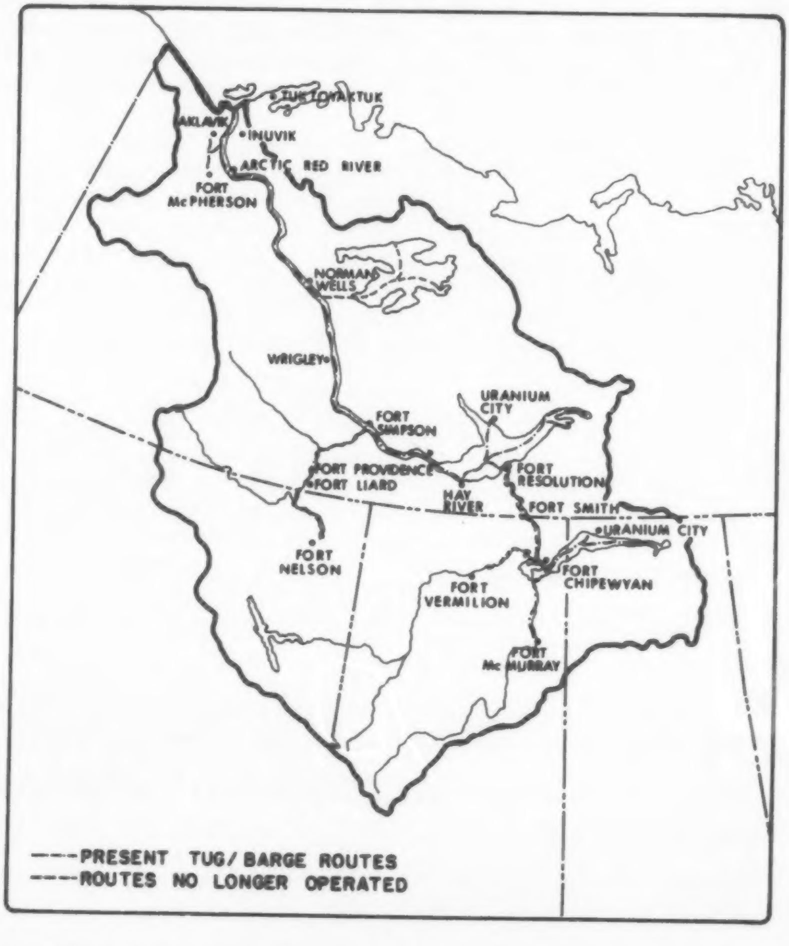
- Mackenzie River (from Hay River to Tuktoyaktuk, and including the Peel River and Arctic Red River),
- Athabasca River and Lake Athabasca system including Peace River and Slave River,
- Great Slave Lake,
- Liard River and Fort Nelson River system,
- Great Bear River and Great Bear Lake system - no commercial marine transportation past September 1980, and
- Williston Lake Reservoir on the Peace River system, B.C.

The main Mackenzie River system covers 1800 km between Hay River and Tuktoyaktuk, the main receiving and trans-shipment point for offshore drilling supplies and Canadian western Arctic cargo. As part of the Mackenzie system, two communities are serviced on the Peel River, Fort McPherson and Aklavik.

In 1979 there were 233 vessels with a gross tonnage of 96 800 tonnes registered by the Canadian Transport Commission (CTC) for use on the river. Of this, the Northern Transportation Company Ltd. (NTCL) operated over 160 barges and 14 tugs, representing over 80 percent of the total freight capacity.

In 1980 there were three operators licensed to carry freight within the Mackenzie River system. The Northern Transporation Company Limited (NTCL), with 14 tugs and about 160 river barges, operates from Hay River for community re-supply and transport of exploration related cargo. The Arctic Transportation Limited

Figure 98. TRANSPORTATION ROUTES - MACKENZIE RIVER SYSTEM (Dickins, 1980).


TUKTOYAKTUK
AKLAVIK
INUVIK
ARCTIC RED RIVER
FORT McPHERSON
NORMAN WELLS
WRIGLEY
FORT SIMPSON
URANIUM CITY
FORT PROVIDENCE
FORT LIARD
FORT RESOLUTION
HAY RIVER
FORT SMITH
URANIUM CITY
FORT NELSON
FORT CHIPEWYAN
FORT VERMILION
FORT McMURRAY
---PRESENT TUG/BARGE ROUTES
----ROUTES NO LONGER OPERATED

(ATL) operates four tugs and 17 barges out of Hay River and Tuktoyaktuk, moving cargoes to oil exploration sites. The Cooper Barging Service Limited, with three tugs and five barges, is licensed to operate anywhere in the Mackenzie system, though it primarily serves Fort Nelson and Liard River.

Cargo types include bulk fuel, chemicals, and dry cargo. Bulk fuel in barge tanks enters the system at Hay River and Norman Wells, and dry cargo enters mainly at Hay River. Fuel from Norman Wells is generally for community re-supply and is shipped upstream as far as Yellowknife, and downstream and along the Arctic Coast to Spence Bay. Dry cargo is transported to all points, with Inuvik and Beaufort Sea exploration taking the bulk of it.

In 1972, about 390 000 tonnes of cargo were carried on the Mackenzie system north of Lake Athabasca by 212 vessels. CTC considered that the fleet should have been about 25 percent above its actual capacity in order to have adequately serviced the 1972 tonnage. On the basis of growth forecasts related to pipeline activity, the CTC approved licenses in 1973 for 43 additional vessels, effectively a 50 percent increase in capacity (CTC, 1978).

Subsequent to this decision, traffic declined by almost 68 000 tonnes, and the Berger Commission decision of 1976 led to an additional 90 000 tonne decrease by 1979. The present system capacity without serious strain is probably in the range of 450 000 to 500 000 tonnes annually, compared to the 225 000 tonnes actually carried in 1979.

There are four summer ferry crossings on the Mackenzie system:

- across the Liard River near Fort Simpson about 30 km from the junction of the Liard with the Mackenzie River,
- across the Mackenzie River near Fort Providence on the Mackenzie Highway,
- across the Red River and Mackenzie River at Arctic Red River (Dempster Highway), and
- across the Peel River on the Dempster Highway (operated as interim measure using a tug/barge combination).

In 1979, these ferries carried 58 400 vehicles and 125 507 passengers. Unlike their provincial counterparts which serve primarily rural roads, NWT ferries are part of two major highway links to the North - the Mackenzie and Dempster. A possible bridge near Fort Providence has been the subject of debate, but the ferry is likely to remain in place for the next decade. As highways are expanded in the north new ferries will be required. Potential crossing sites are near Wrigley, Fort Franklin on the Bear River, and across the Mackenzie at Norman Wells. Esso Resources have considered the possibility of a temporary air cushion ferry at the Burnt Island crossing to assist advance clearing crews during pipeline right-of-way preparation during freeze-up.

The ice-free season in the main stem Mackenzie River ranges from 164 days at Fort Simpson to about 100 days at Tuktoyaktuk. Spring break-up does not occur sequentially from south to north. Because of high spring inflow from the Liard River, the mid-portion (Fort Simpson to Fort Good Hope) normally breaks out first in late May. The upstream section is delayed about two weeks due to the stabilizing effect of Great Slave Lake, and the downstream section is delayed because of its higher latitude and absence of major tributaries. Ice jams occur regularly at six tributary junctions, sharp bends, and gravel bars. Often the first barge tows of the season overtake the ice in the lower river and are delayed until it clears. In the fall, freeze-up frequently forces the last vessels returning from the north to winter away from Hay River.

Water levels along the Mackenzie system normally peak during late May and early June, due to high mountain runoff in the Liard, Peace, and Athabasca River systems. By mid-July water levels usually start to recede until a minimum is reached in October just prior to freeze-up. There are six main areas where barge draft is limited during low water conditions: Beaver Lake, Providence Rapids, Green Island Rapids, Sans Sault Rapids, Ramparts Rapids, Wrigley Harbour.

Channel conditions in these sections affect the permissible draft loading of the barges and consequently determine the capacity of the system. Time is also required to break up tows in order to relay single barges through these trouble spots and on occasion even lightening to negotiate passage. The 1980 and 1981 seasons were two of the worst years on record for water levels on the Mackenzie system. Abnormally low runoff into the Liard system in 1980 produced depths in the Mackenzie River at the beginning of navigation more often associated with fall operations (see Table 91).

Dredging is provided every year by Public Works Canada vessels. In 1979, 200 000 m^3 were removed from problem areas in the Mackenzie system. This is compared to the over 3.5

million m^3 of dredging considered necessary over a five year period. Recent traffic forecasts appear to have eliminated any chance of this program receiving funding (estimated at $53.5 million in 1976), but the need for improved dredging on the Mackenzie is expressed each year by operators at the Mackenzie/Athabasca Waterway Conferences. Present equipment is considered obsolete and completely inadequate, barely maintaining navigation channels at present levels.

TABLE 91. CRITICAL LOW WATER LEVELS GOVERNING TRANSPORTATION ON THE MACKENZIE RIVER (DICKINS, 1980)

LOCATION	NEAREST STAGE RECORD	MINIMUM ACCEPTABLE STAGE M	OCTOBER 1, 1980 READING M
FT. PROVIDENCE RAPIDS	FT. PROVIDENCE	2.5	2.41
BEAVER LAKE	FT. PROVIDENCE	2.5	2.41
GREEN ISLAND RAPIDS	FT. SIMPSON	4.8	4.72
RAMPARTS RAPIDS	FT. GOOD HOPE	1.8	1.11
SANS SAULT RAPIDS	SANS SAULT	3.8	N/A

NOTE: SINCE RELIABLE RECORDS HAVE BEEN MAINTAINED FOR THE MACKENZIE R. WATER LEVELS HAVE NEVER BEEN LOWER THAN THE FALL OF 1980

AT OCTOBER LEVELS, TUGS ARE HITTING BOTTOM AND DAMAGING HULLS, RUDDERS, PROPS ETC. IN AN EFFORT TO GET BACK TO HAY RIVER FOR THE WINTER

Environment Canada maintains automatic level stations at four locations on the river. From this data a regular forecast of water levels is provided to assist operators.

There is now almost no commercial vessel traffic on the Peace River. Three companies operate a combined fleet of nine small tugs and six barges on Williston Lake in British Columbia in support of the logging industry and mining exploration. The ice free navigation season on Williston Lake is typically from May 15 to December 1.

The Athabasca system has its southern terminus at Fort McMurray. To the north the system terminates at Fort Fitzgerald on the Slave River in a series of rapids stretching 26 km downstream (site of proposed Slave River hydro-electric development). Past these rapids the river is again navigable as far as Great Slave Lake. With the relocation of NTCL's terminal to Hay River in 1965, commercial barge traffic on the lower Slave River effectively ceased. Fort Smith is now connected by all weather road to the Mackenzie Highway system. Today there is little or no traffic on the Peace and Slave Rivers, and only about 800 km of the total 1280 km of navigable routes are actually utilized.

In 1980 there were only six tugs and less than 30 barges on Lake Athabasca. However, these vessels moved 95 000 tonnes on the Athabasca system. Over the past ten years Athabasca system tonnages have ranged from a low of 22 500 tonnes in 1973 to a high of 95 000 tonnes in 1980. Since [illegible], freight in the Athabasca area has increased by over 400 percent, until it now accounts for 30 percent of the total Mackenzie basin waterborne tonnage (325 000 in 1979). This growth can be mainly attributed to the increased mining exploration activity in Saskatchewan and to a lesser extent oil sands development in Alberta.

Only NTCL is licensed to provide general unrestricted freight services within the Lake Athabasca system. The only licensed independent operator, based in Uranium City, operates with two tugs and one barge. Its license is restricted to charter only, and the company caters mainly to exploration. A new highway to the south shore of Lake Athabasca could provide more freight in the way of heavy exploration cargoes. Such a highway would cut into NTCL's community re-supply operations.

The Alberta Government operates four summer cable ferries within the Peace/Athabasca drainage area, two across the Peace River, and one across each of the McLeod and Athabasca Rivers. The B.C. Department of Highways operates a tug/pontoon barge ferry across the Peace River near the Alberta border.

The Athabasca and Slave Rivers offer one of the longest navigation seasons within the Mackenzie basin, with break-up between late April and mid-May, and freeze-up from early to mid-November. Lake Athabasca is not open to navigation until June 1.

Barge loading drafts on the Athabasca system are governed mainly by water levels at the mouth of the Athabasca River in the area of Big Point Channel, and on the Chenal des Quatre Fourches. Dredging has always been necessary to assist barges into the lake. Channels are dredged 60 m wide to a maximum depth of 1.6 m, but low water levels can restrict permissible draught to one metre or less, which effectively reduces carrying capacity by 50 percent. Low water levels on Lake Athabasca can lead to docking problems at Uranium City and Fort Chipewyan, as well as other points where exploration cargoes may have to be unloaded.

During the 1968-1971 period, extremely low water levels were associated with the reduction in Peace River flows while the Williston Lake reservoir was being filled. Annual dredging requirements in parts of the Athabasca delta had to be doubled. Fifteen extra navigational aids were required during this period to mark newly exposed shoals. The Canadian Coast Guard noted at the 1980 Mackenzie/Athabasca Conference that the 1979 Athabasca dredging program was completely inadequate to maintain safe navigation.

Great Slave Lake is open for navigation for about 125 days each year from mid-June to mid-October. An integral part of the Mackenzie system, it provides a water transportation route between Hay River, the northern rail terminus, and ports on the lake. Petroleum products account for most of the Great Slave tonnage. In 1977 NTCL moved 32 000 tonnes between Hay River and the above ports.

The Liard River is navigable by tugs and barges for about 12 km upstream from its junction with the Mackenzie River, where it ascends over 16 km of minor rapids navigable only by powerful shallow draft vessels. This critical navigation section provides very strong currents in June when water levels are high. By about August, water in the rapids is too shallow for most barges.

The Fort Nelson River, a tributary of the Liard, is navigable as high as Fort Nelson, although in many areas the channel is less than 20 m wide. Water levels are usually satisfactory on this system from May 20 to late July. Problems are encountered with draught after early August. The Fort Nelson River has natural variations up to 12 m in one season. Only one operator presently operates on the Liard/Fort Nelson system with three tugs and five barges. In the past four years, low water in the fall at Fort Nelson has prevented the operator from drydocking its vessels.

The B.C. Department of Highways operates an Air Cushion Vehicle cable ferry year-round across the Fort Nelson River at Fort Nelson. The NWT Department of Highways operates a self propelled ferry across the Liard River near Fort Simpson.

Great Bear Lake has the shortest navigation season of less than 60 days, and is subject to often violent storms. In 1980, NTCL decided to permanently terminate operations. In future, communities will be resupplied by winter road and aircraft.

Future Developments

Future developments in transportation use of water in the Arctic drainage region depend upon industrial expansion, highway construction, and developments that would affect river flows. A more detailed account of these factors than in the following summary is contained in Dickins (1980).

The only major resource development likely to happen within the next five years along the Mackenzie River system is the proposed Norman Wells oilfield expansion and a pipeline to northern Alberta. The environmental impact statement indicates that the potential impact of this project on Mackenzie barge traffic will be minimal. Esso Resources considered barge transport of oil as an alternative to the pipeline, but this was rejected due to winter storage requirements, spill risk, and technical difficulties.

As proposed, the oilfield expansion will involve six artificial islands in the Mackenzie River which could cause ice jamming in the spring, and sediment deposition tails, which may require maintenance dredging to enable unimpeded navigation.

For the immediate future there appears to be no other major new project that will place a significant demand on the Mackenzie water transportation system. Present plans for Beaufort Sea oil production facilities, and a renewed interest in a Mackenzie Valley pipeline, could change this forecast. U.S. offshore oil and gas lease sale development near Prudhoe Bay is proceeding and could lead to major expansions to North Slope production facilities. This development could require the Mackenzie waterway for logistics support to complement the often unreliable Pt. Barrow sealift route. A recent report on future major projects indicates two gas plants near the Mackenzie delta and a gas pipeline between there and Whitehorse, all to be developed after 1985 (MPTF, 1981). The impact of these projects on the Mackenzie River transportation system is unknown. The same report, however, forecasts an estimated $150 million expansion to the Mackenzie River barge systems.

The Mackenzie Highway, Dempster Highway, and Pine Point Railway have all contributed to a decline in water transportation. Possible new highway routes include: a road from Norman Wells to Ross River, YT, though unlikely in the next five years; an extension of the highway from Fort Simpson to Norman Wells, which would require major new resource development for justification; and; which is more likely, a new highway from Fort Nelson to Fort Liard and Fort Simpson to connect with the Mackenzie Highway.

In northern Saskatchewan there is a possibility of completing a road from Peter Pond Lake, Buffalo Narrows to the southern shore of Lake Athabasca primarily in support of mineral exploration. This route exists at present as a winter road only.

Dam projects upstream of navigable waters can adversely affect navigation during the critical period of reservoir filling. The long-term effects of flow regulation, although not necessarily a detriment to navigation water levels, are still not fully understood (Dickins, 1980). The main source of present Mackenzie system flow regulation is the Bennett Dam on the Peace River. Navigation effects of this project have been discussed.

The maintenance of adequate water levels in the Mackenzie system is a concern both for provision of navigation and preservation of the environment. The Navigable Waters Protection Act, administered by Transport Canada, requires federal approval for any construction in navigable waters. However, the Act may not cover a situation where a dam built on a non-navigable headwater stream would seriously affect downstream navigation (Mackenzie River Valley, pipeline submission - 1976).

Hydro-electric sites being considered that could affect navigation within the Mackenzie drainage basin in the future include a possible dam on the Slave River, Dunvegan and Site C on the Peace River, and sites on the Liard River.

The Slave River development and the two proposal sites on the Peace River are all "run-of-the-river" hydro projects. For this reason, none is expected to pose substantial ongoing effects on downstream flows, although there may be short term effects during construction. R.L. Walker (1981) has indicated that the

Slave River reservoir filling period "...would briefly result in lower flows in the Slave River entering Great Slave Lake and hence some lowering of water levels. The effects would be small and of little consequence to downstream users".

A feasibility study is examining a number of potential dam sites and reservoirs on the Liard River. A complete study of downstream effects from the selected location(s) will not be available until 1982. Concerns have been expressed that reservoir storage on the Liard could delay spring ice break-up. During high flow summer months the same storage would reduce peak flows, to the benefit of downstream Liard navigation. Fall effects of river regulation on levels are not anticipated to be of great significance.

In addition to the developments reviewed above, there have been occasional suggestions made regarding possible transfer of water from the Mackenzie River system to the Saskatchewan River system (see, for example, Dickins, 1980). Billing (1981) has raised concern about possible effects of such transfers on northern transportation.

Water Quality

Water quality effects of transportation include the cumulative effects of regular vessel discharges into the river system (bilge water, sewage, grey water (slop), engine oil, and garbage) and pollution resulting from the transport of hazardous materials, including petroleum products. The latter could take the form of catastrophic structural failure of a barge tank (collision, grounding, sinking) while in transit, slow leakage through cracked tanks, and spills during ship to shore transfer operations.

Environment Canada considers pollution of the first type to be insignificant, even with the increased traffic that would be associated with a major pipeline or oil/gas discovery (Dickens, 1980). In areas where a large number of vessels are together at one time, particularly near a community intake, vessel discharge could become a concern. With this in mind, periodic monitoring of water quality is undertaken in areas of heavy vessel congregation (eg., Tuktoyaktuk, Inuvik, Hay River). To date no serious incident associated with vessel pollution has occurred on the Mackenzie/Athabasca system, though there have been complaints of fuel oil contamination in the Hay River.

In spite of proven lack of a serious vessel sewage discharge pollution problem on river systems, federal regulations under the Canada Shipping Act will likely apply to vessels on the Mackenzie/Athabasca and Lake Winnipeg/Nelson River systems within two years. Regulations now in force with regard to sewage discharge apply only to Great Lakes inland carriers.

Regarding the second pollution hazard, a number of factors are involved. All fuel transfer operations are strictly enforced by the Canadian Coast Guard. The potential exists, however, for a major spill of over 250 m^3 in the event of tank rupture through grounding, structural failure, and/or collision. The Mackenzie system has a number of fast flowing shallow areas where navigation can be quite treacherous, especially during low-water years. Although a major oil pollution incident has not occurred to date, an incident if it did occur would impose a very difficult clean-up operation. Vast stretches of shoreline would be contaminated before containment devices could be deployed. The territorial government alone ships over 18 000 m^3 of heating oil and gasoline each year via the Mackenzie River, and this figure can be expected to increase steadily as the NWT population grows. ATL moved over 30 000 m^3 of fuel from Hay River to the Beaufort Sea in 1979.

There is a reporting procedure whereby vessel operators are required to notify the territorial government and Environment Canada of any significant spill incident. However, there is no coordinated action plan whereby clean-up responsibilities and logistics are defined for dealing with a major barge spill incident on the river system.

Dickins (1980) has criticized the lack of preparedness for such incidents and has recommended that a preliminary risk analysis be undertaken of petroleum products and other hazardous cargo shipments on the Mackenzie/Athabasca system. Difficult navigation areas should be highlighted in order of risk and downstream environmental sensitivity assessed at each location (shoreline type, community proximity, etc.). This information should then form the basis for a Mackenzie River Oil Spill Contingency Plan to be developed in co operation with governments and operators.

APPENDIX

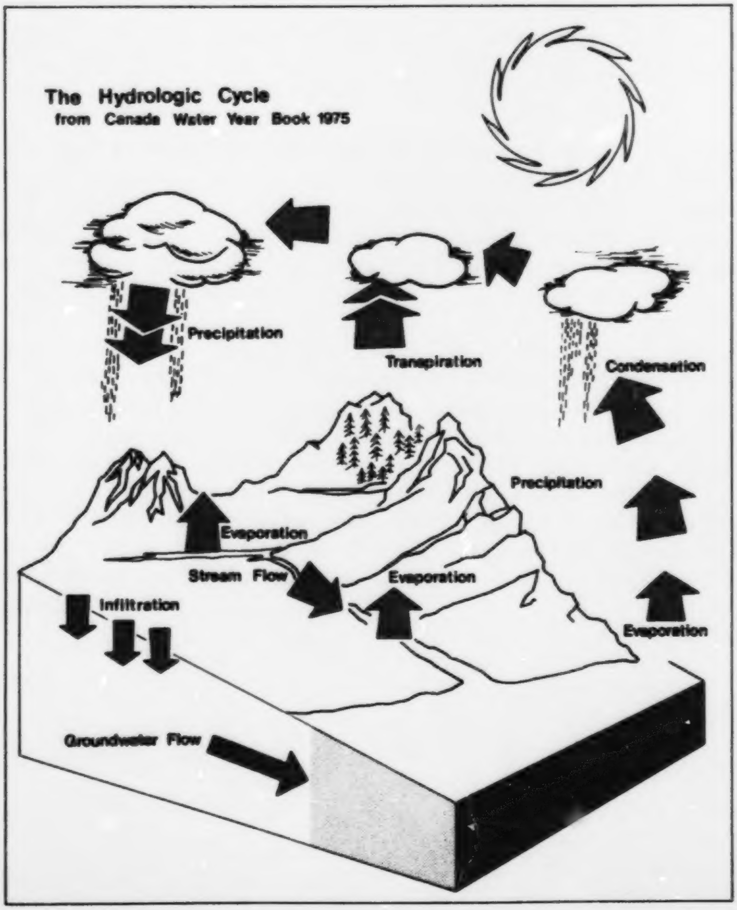
HYDROLOGY PRIMER

HYDROLOGY PRIMER

Some of the sections contained in this report unavoidably use terminology or refer to processes that are not usually known to the general public. There are also terms which are not always used with consistency in the literature. Therefore, the following primer is offered for interested readers.

The hydrologic cycle (Figure 99) is the sequence of stages that ensures the renewability of the water resource, including precipitation, surface and sub-surface drainage, evaporation and transpiration, and atmospheric transport.

Figure 99. THE HYDROLOGIC CYCLE (Environment Canada, Canada Water Year Book, 1975).


The Hydrologic Cycle
from Canada Water Year Book 1975
Precipitation
Transpiration
Condensation
Precipitation
Evaporation
Stream Flow
Evaporation
Infiltration
Evaporation
Groundwater Flow

Liquid precipitation is mobile. On reaching the land, water, or plant surface, it may soon re-enter the atmosphere by being evaporated or transpired. The former process refers to the atmospheric uptake of water from an open water area such as the surface of a lake or reservoir. The latter process involves water being taken into plant tissue, then lost as vapour back to the atmosphere. Sometimes it is convenient to consider the two together, as evapotranspiration.

Other rainfall falls upon, or drains directly to, surface drainage networks. Here it is still subject to eventual evaporation, either from its fresh water or subsequent marine stages. Drainage to marine bodies is the fate of large volumes of continental waters. However, there do exist some large land areas which are "closed", so that internal surface drainage ends in lakes which are often highly saline due to the effects of evaporation.

Another important component of the hydrologic cycle is the ground water. Surface waters which sink into the soil become "soil moisture" until they reach the level at which there is saturation. This is the "water table", the surface of the bodies of ground water that can move through permeable layers or aquifers, sometimes reaching surface water bodies in lowlands. When ground waters drain to rivers, lakes, etc., this is known as discharge. When surface waters drain to the ground water regime, this is known as recharge.

When precipitation is solid and not mobile, it accumulates in storage as snow or ice. Although glaciers are an interesting and important part of the hydrologic cycle, they are a long-term phenomenon associated with a small total area, and the annual accumulation and melt of snowfall in the Study Region is of more significance. Some exchange of water between its solid and vapour states also occurs in a process called sublimation.

In this report, the portion of the hydrologic cycle given most attention is the surface drainage. Terms requiring explanation relate to statistics of flow and the various works constructed for the artificial control of flow.

At some locations in the Study Region, streamflow has been recorded for over 70 years. Published records (e.g., Environment Canada, 1980a) normally display this information as daily, monthly, and annual mean flows for each year. From these can be calculated mean monthly and mean annual values. Examples of these and other statistics, and an explanation of each, are given below (see Tables 19 and 45):

Daily Mean Flow - the average flow during a day (e.g., 1.58 m^3/s, February 7, 1937, Assiniboine River at Brandon).

Monthly Mean Flow - the arithmetic average of daily mean flows for a specific month. (Referred to as monthly flows) (e.g., 1.73 m^3/s, February 1937, Assiniboine River at Brandon).

Mean Monthly Flow - the arithmetic average of the monthly mean flows for a calendar month for the historical period of record (e.g. 4.69 m^3/s, February, Assiniboine River at Brandon).

Annual Mean Flow - the arithmetic average of the monthly mean flows for a specific year. (e.g., 6.77 m^3/s, 1937, Assiniboine River at Brandon).

Mean Annual Flow - the arithmetic average of the annual mean flows for the historical period of record. (e.g., 31.1 m^3/s, Assiniboine River at Brandon).

Median Monthly Mean Flow - the monthly flow that is equalled or exceeded 50 percent of the time for the historical period (referred to as the median flow).

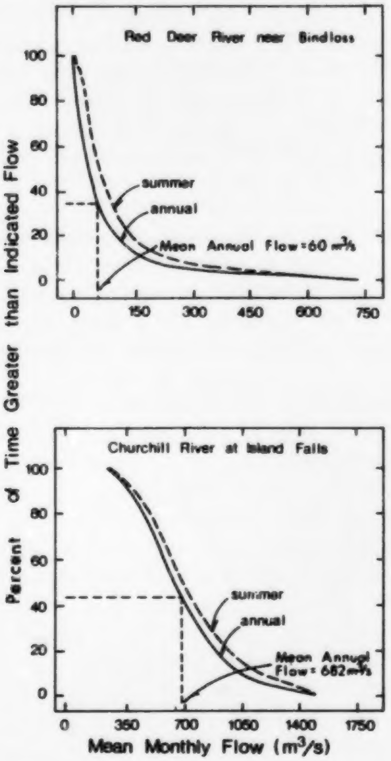
Computed Natural Flow - refers to the flow that would have occurred if man had not intervened by diverting, storing, or consuming the water anywhere upstream of the point of measurement.

In considering the hydrologic significance of the mean annual flow, it can be said that it approximates the maximum firm flow that can be developed on a stream if storage works are put in place. How closely a firm flow could approximate a natural mean annual flow, considering the historical record, would depend of the magnitude of reservoir losses (evaporation, seepage) and the size of the reservoirs. It is estimated that 75 to 85 percent of the mean annual flow is the maximum firm flow that can be developed in any stream because evaporation losses are significant and flood flows in high water years can seldom be stored or utilized. The median annual flow also serves to approximate the firm flow.

Flow Duration Curves

Flow duration analyses can be undertaken using monthly mean flow data, for either annual or summer periods. To construct an annual flow duration curve, the monthly mean flows for the period of record are ordered smallest to largest and a curve constructed relating monthly mean flow to the expected percent of time that the flow is greater than the indicated flow. A similar analysis can be performed considering only the summer (April to October) monthly mean flows (Figure 100).

Figure 100. EXAMPLES OF FLOW-DURATION CURVES (WER, 1980a).



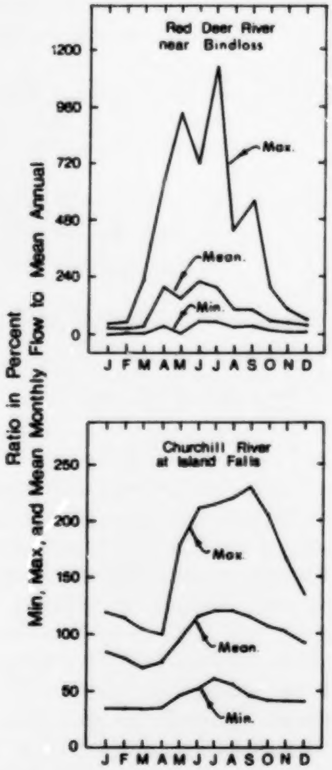
When the two curves are plotted together the summer curve always plots to the right of the annual curve indicating that, as would be expected, any particular flow has the same or a higher frequency of recurrence in the summer than when considered for the annual period.

The flow duration curve can be used to determine the historical dependability of any particular monthly mean flow. Dependability criteria are often specified to evaluate the adequacy of an existing water supply for a specified use. For example, the summer flow duration curve can be used to determine the development potential of an irrigation project since irrigation demands generally only occur during the summer period. If hydro power is the intended use, the monthly mean flow that could be depended on, say 98 percent of the time, might be specified as the firm power development potential of a stream using the annual flow duration curve.

Flow-Ratio Hydrographs

A plot of the monthly mean flow versus time in months shows the general manner in which the runoff is distributed throughout a given year on a monthly basis. Flows in any particular month can vary from year to year, however, and the average distribution as represented by the mean monthly flow tends to represent the distribution of runoff that generally occurs from year to year. The average hydrograph is constructed from the plots of the mean monthly flows.

Figure 101. EXAMPLES OF FLOW-RATIO HYDROGRAPHS (WER, 1980a).



A problem that arises when comparing the variability of mean monthly streamflows for two stations is the difference in the relative magnitudes of the flows because of differences in hydrologic response and basin size above the station. Therefore, to facilitate comparisons between stations of the average variation, a plot can be made of the ratios (in percent) of the mean monthly flows to the mean annual flow for each calendar month. This can also be done for the historical maximum and minimum monthly mean flows for each calendar month. Plots for the Red Deer River near Bindloss and the Churchill River at Island Falls (Figure 101) illustrate that the Red Deer River experiences, on the average, its peak monthly flow in June with a mean monthly flow 2.2 times its mean annual flow, whereas the Churchill River peaks in July at just slightly above its mean annual flow rate and experiences a more sustained flow for the remainder of the year. These "hydrographs" have the same shape as a plot of mean monthly discharges but must be multiplied by the mean annual flow and divided by 100 to obtain the discharge.

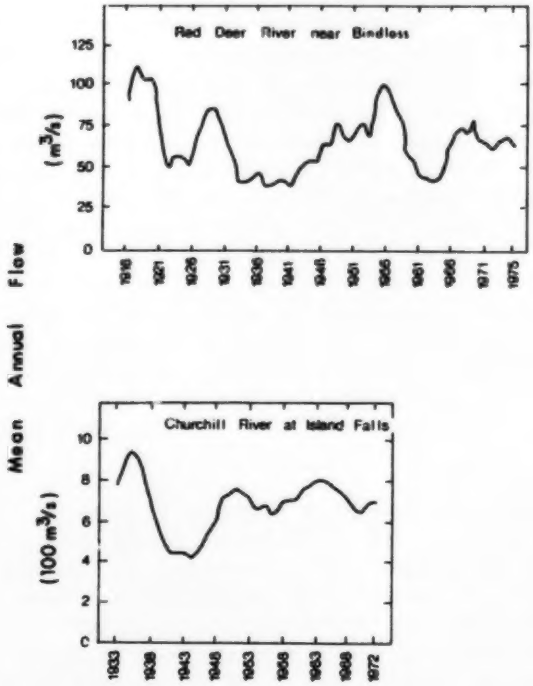
The mean monthly flow-ratio hydrographs show the average distribution of flow over the year whereas the maximum and minimum ratios show the type of variability that could occur in any month from year to year. The July flows for the Red Deer River (up to 11 times its mean annual) have a greater potential for variation from year to year than those for the Churchill, whereas January monthly flows on the Red Deer River are less vairable that those on the Churchill. The Churchill River's maximum monthly flow was only 2.3 times its mean annual indicating that it has less potential for relatively extreme flows, although it should be kept in mind that the periods of record are different. It should be noted that the plots represent independent months and do not represent an actual composite of flow for a year. That is, it is extremely unlikely that the means, maximums, and minimums for each month occurred in the same year.

When comparing the mean monthly flow-ratio hydrographs for two stations it can be said that, for any given month, the station having the larger ratio records, on the average, a higher percentage of its annual flow in that month than does the other station. The station having the largest difference between ratios of maximum and minimum monthly mean flows to mean annual flow has a greater variability from the mean from year to year of monthly mean flows for that month.

Other Statistical Parameters

Five-year means can be calculated on successiver 5-year annual flows and plotted using the last year in the 5-year series for each station as a plotting position. For a station that had a period of record from 1912 to 1973 the first moving mean would be derived from the 1912 to 1916 annual flows and plotted using the year 1916 (Figure 102). The second mean would be derived from the 1913 to 1917 annual flows, and so on. This successive averaging tends to smooth out variations in annual flow that occur from year to year but indicates any tendencies to periodicity for wet and dry periods. Generally, the closer the plot approximates a horizontal line with little variation between the highs and lows the more dependable is the flow from year to year.

Figure 102. EXAMPLES OF FIVE-YEAR MOVING MEAN GRAPHS OF MEAN ANNUAL NATURAL FLOWS (WER, 1980a).



Mean annual and median monthly flows can be determined for any station that has a reasonable period of record. To facilitate comparisons between stations of the median monthly flows, the ratio of the mean annual flow to the median monthly flow can be calculated for each station. If the mean annual flow is less than the median monthly flow, the ratio will be less than 1.0 and it can be said that, considering the historical record, monthly mean flows are greater than the mean annual flow more than fifty percent of the time. For two stations, the station with the lower ratio has a greater frequency of monthly flows that are larger than the mean annual flow.

For any location the maximum monthly mean flow for the period of record can be determined and divided by the mean annual flow. This ratio can be used as an indicator of the rivers that have experienced the greatest deviation of monthly mean flows from the mean annual. This statistic is also an approximate index of the degree of variability that can be expected at a station from month to month during the runoff period.

The coefficient of variation is calculated as the ratio of the standard deviation of the annual mean flows to the mean annual flow. This statistic can be used to compare the average variability of annual flows from year to year between stations. The larger this ratio, the greater is the variation that can be expected, on the average, between successive annual mean flows at a station, assuming that annual flows are relatively independent events.

GLOSSARY OF UNITS

In keeping with national and worldwide trends, this report was prepared using metric units. In cases where traditional usage is entrenched, such as the use of "acres" for land areas in agriculture, both metric and traditional units are employed.

m^3/s - cubic metres per second
- 1 m^3/s equals 35.3 cubic feet per second (cfs)

m^3/s	approximate average flow rates of streams near their mouths*	cfs
1-3	small prairie creeks	35-100
8	Qu'Appelle River	275
9	Battle River	320
15	Souris River	530
50	Assiniboine River	1 750
70	Red Deer River	2 475
100	Bow River	3 500
150	Red River (Manitoba)	5 250
250	North Saskatchewan River	8 750
2 000	Peace River	70 000
10 000	Mackenzie River	350 000

dam^3	- cubic decametres (1 decametre = 10 metres) - 1 dam^3 is a volume equal to 0.81 acre feet
hectare	-1 hectare (ha) equals 2.47 acres
litre	- 1 litre (L) equals 0.22 Imperial gallons - 1 litre equals 0.001 m^3

* Average flows for any given year can vary significantly from these values.

Table 92 which follows provides precise conversion factors for metric to imperial measures, or vice versa.

TABLE 92. METRIC-IMPERIAL CONVERSION TABLE

TO CONVERT FROM IMPERIAL TO METRIC MULTIPLY BY	METRIC	IMPERIAL	TO CONVERT FROM METRIC TO IMPERIAL MULTIPLY BY
2.54*	CENTIMETRE (CM)	INCH (IN.)	.393 701
0.304 8*	METRE (M)	FOOT (FT.)	3.280 84
0.914 4*	METRE (M)	YARD (YD.)	1.093 61
1.609 344*	KILOMETRE (KM)	MILE (MI.)	.621 371
6.451 6*	SQUARE CENTIMETRE (CM^2)	SQUARE INCH (IN.^{2})	0.155 000
0.092 903 04*	SQUARE METRE (M^2)	SQUARE FOOT (FT.^{2})	10.763 9
0.836 127	SQUARE METRE (M^2)	SQUARE YARD (YD.^{2})	1.195 99
2.589 988	SQUARE KILOMETRE (KM^2)	SQUARE MILE (MI.^{2})	.386 102
0.404 686	HECTARE (HA)	ACRE (AC.)	2.471 05
16.387 064*	CUBIC CENTIMETRE (CM^3)	CUBIC INCH (IN.^{3})	0.061 023 7
0.028 316 8	CUBIC METRE (M^3)	CUBIC FOOT (FT.^{3})	35.314 7
0.764 555	CUBIC METRE (M^3)	CUBIC YARD (YD.^{3})	1.307 95
1.233 482	CUBIC DECAMETRE (DAM^3)	ACRE-FOOT (AC.-FT.)	0.810 713
4.546 09*	LITRE (L)	GALLON (GAL.)	0.219 969
0.159	CUBIC METRE (M^3)	BARREL-OIL (BBL.)	6.29
28.349 5	GRAM (G)	AV. OUNCE (OZ.)	0.035 274 0
0.453 592 37*	KILOGRAM (KG.)	AV. POUND (LB.)	2.204 62
0.907 184 74*	TONNE (T)	TON (2000 LB.)	1.102 31
3.6*	MEGAJOULE (MJ)	KILOWATT·HOUR (KWH)	0.277 778
0.075 768 2	LITRE PER SECOND (L/S)	GALLON PER MINUTE (GAL./MIN.)	13.198 2
0.028 316 8	CUBIC METRE PER SECOND (M^3/S)	CUBIC FOOT PER SECOND (CFS.)	35.314 7
0.555*	CELSIUS DEGREE (C°)	FAHRENHEIT DEGREE (F°)	1.8*

*EXACT CONVERSION FACTOR

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